

Observational Signatures of Magnetic Reconnection in the Extended Corona

SabriNA SAverage,

Matthew J. West, Daniel B. Seaton, Adam Kobelski



Supra-Arcade Downflows (SADs) Observations



Sadpoles, not tadpoles

Fig 1

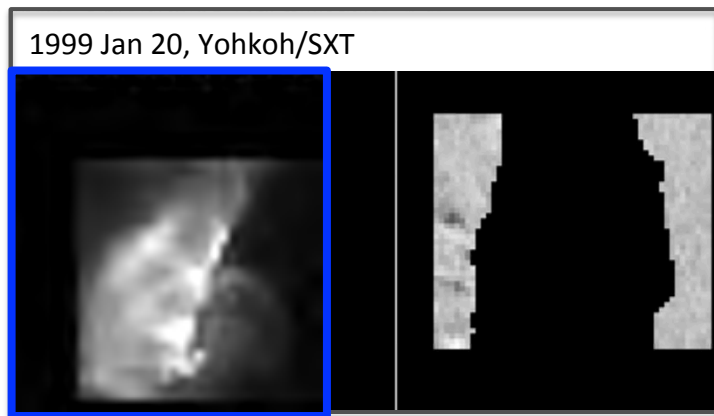


Fig 2

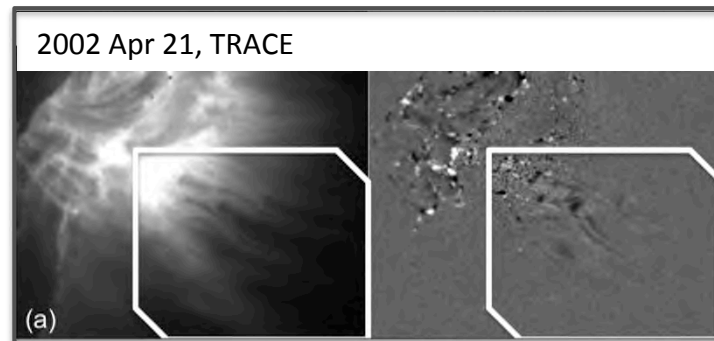


Fig 3

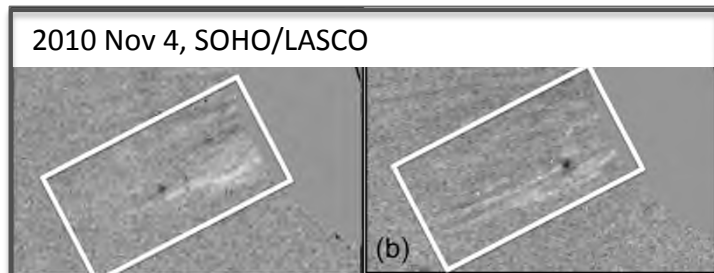
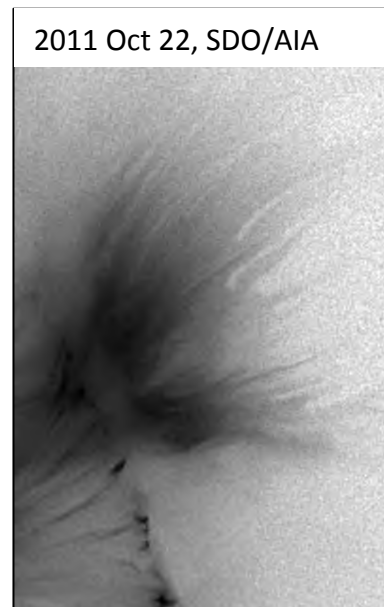
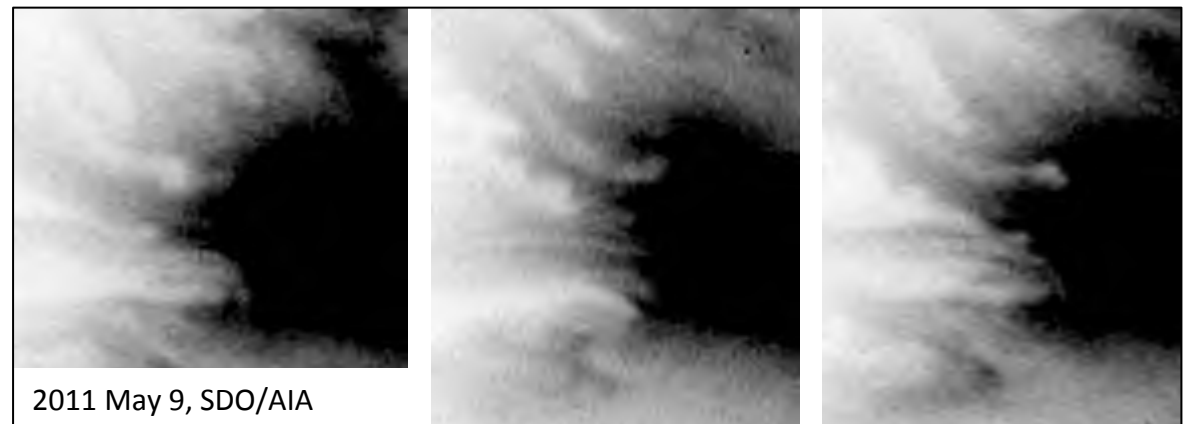


Fig 4



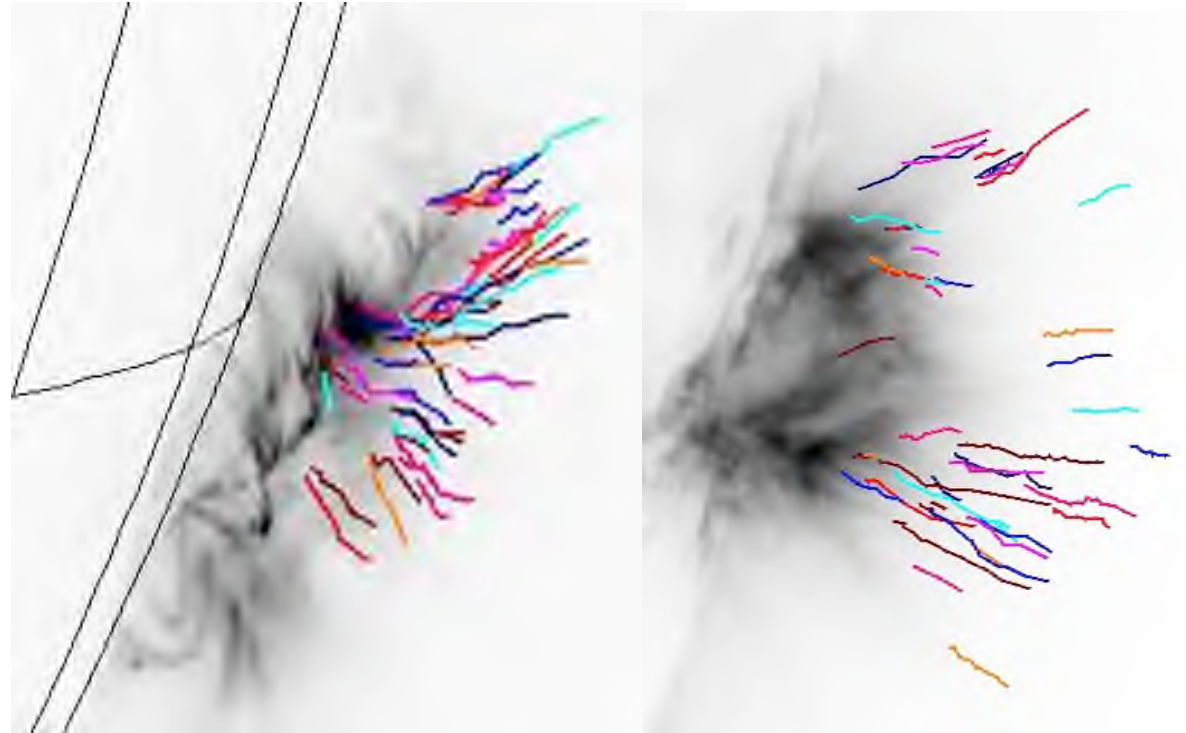
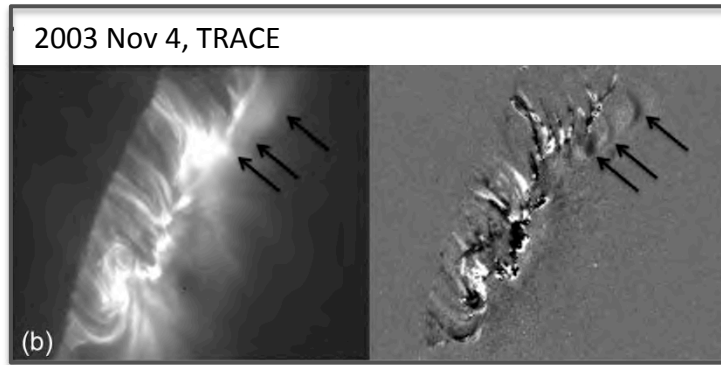
- Teardrop-shaped **voids** observed to travel sunward through the bright, hot fan extending outward along the spine of developing post-flare arcades.
- Observed with high-temperature instrumentation (EUV, X-ray) & white-light coronagraph (density)
- **LONG DURATION EVENTS**

Fig 5



Supra-Arcade Downflowing Loops (SADLs) Observations

Fig 1



Supra-Arcade Downflowing Loops (SADLs) Observations

Fig 1

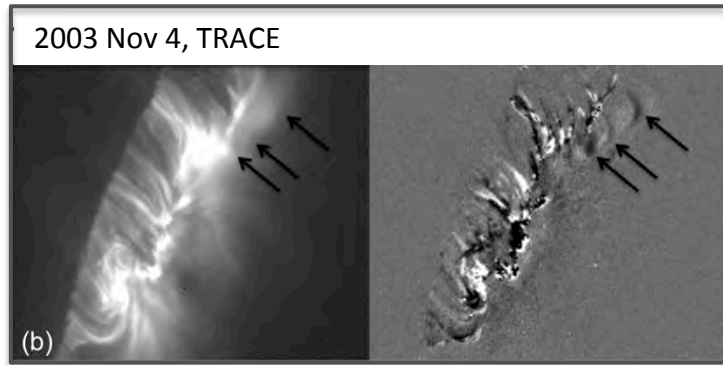
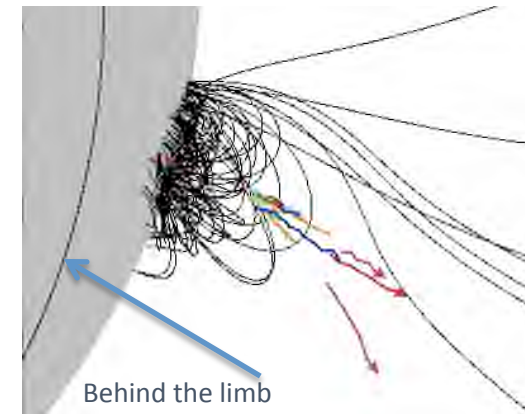
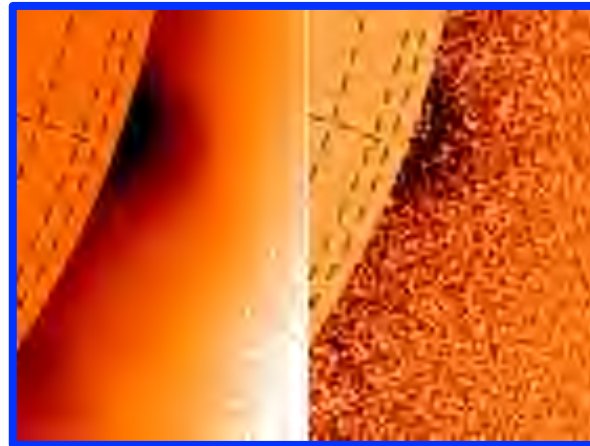
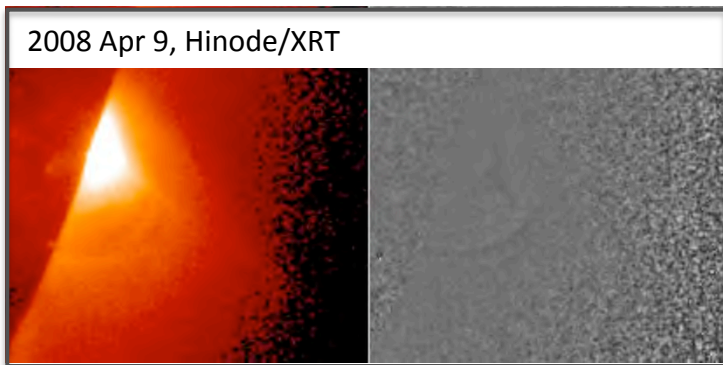


Fig 2



Supra-Arcade Downflowing Loops (SADLs) Observations

Fig 1

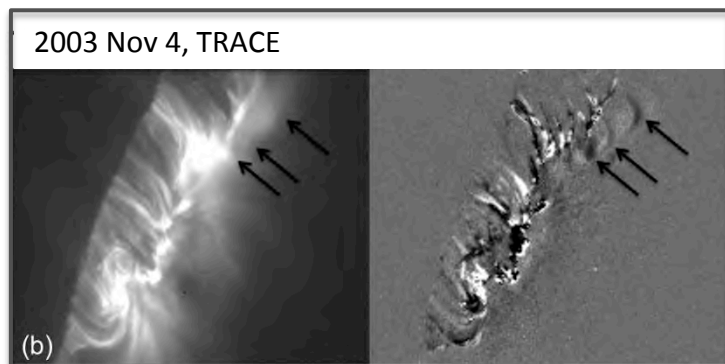
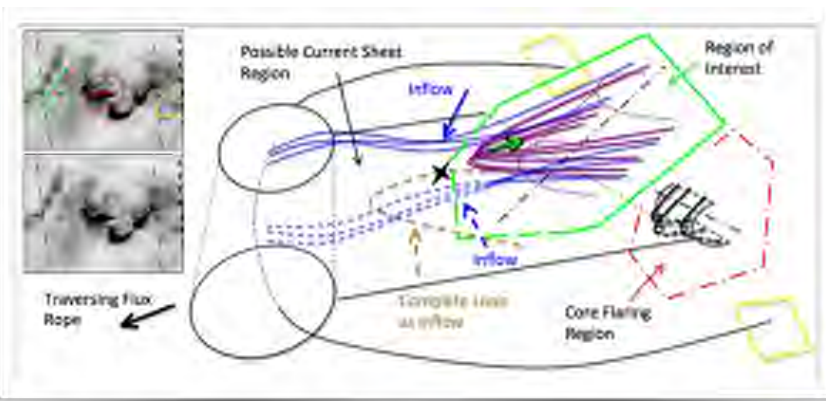
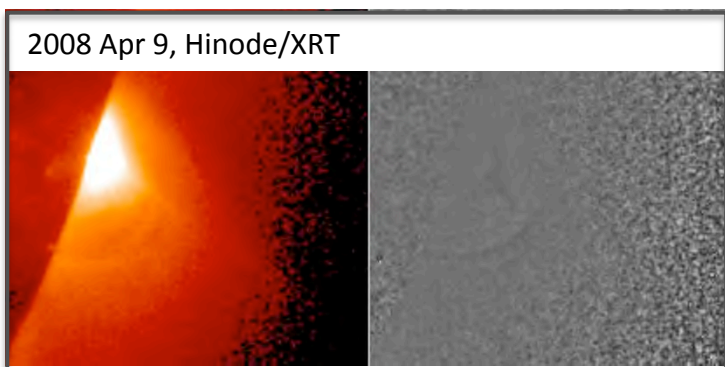


Fig 2



2010 Nov 3, SDO/AIA

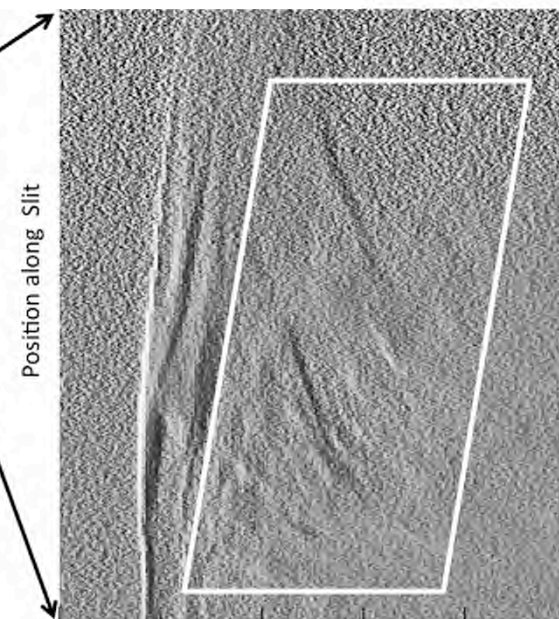


Fig 3

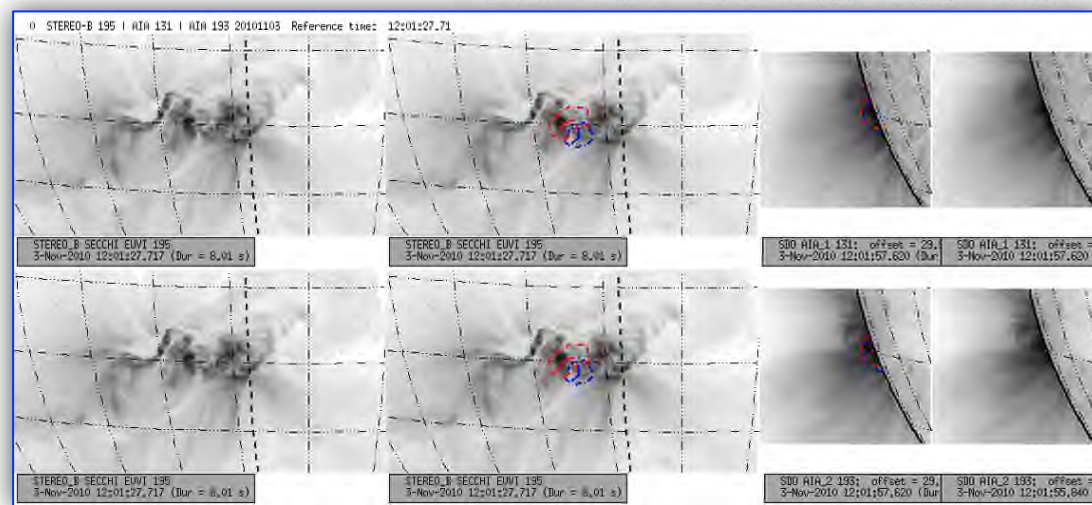


Fig 1: Savage & McKenzie 2011

Fig 2: Savage et al. 2010

Fig 3: Savage et al. 2012

Different from Plasmoid Observations

- Coherent 'bubble' of **emitting** plasma held together by magnetic fields.
- Observed with broadband-temperature instrumentation (EUV, X-ray, Hard X-ray) & white-light coronagraph (density)

➤ Magnetic Islands

Fig 1

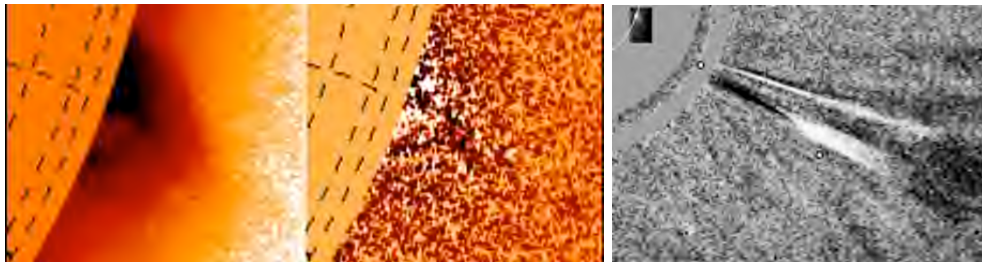


Fig 2

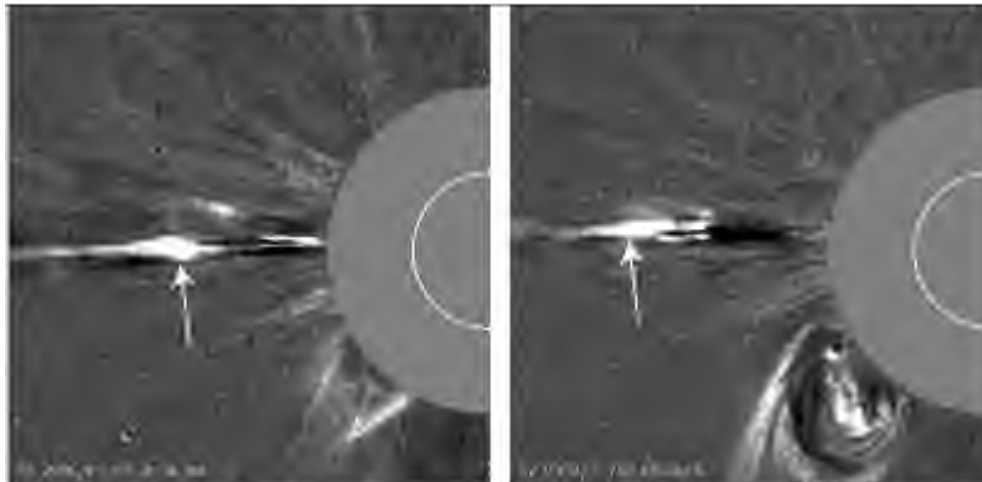


Fig 3

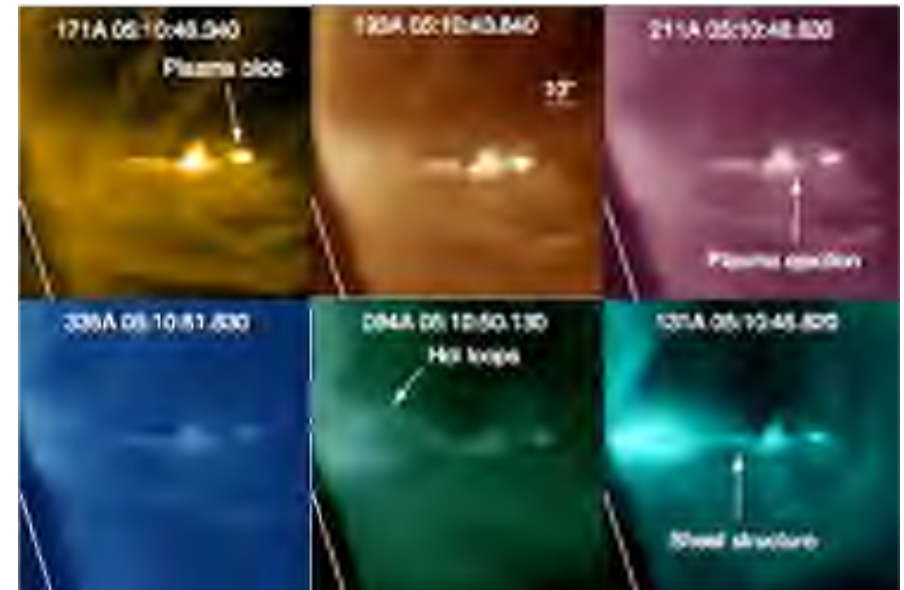
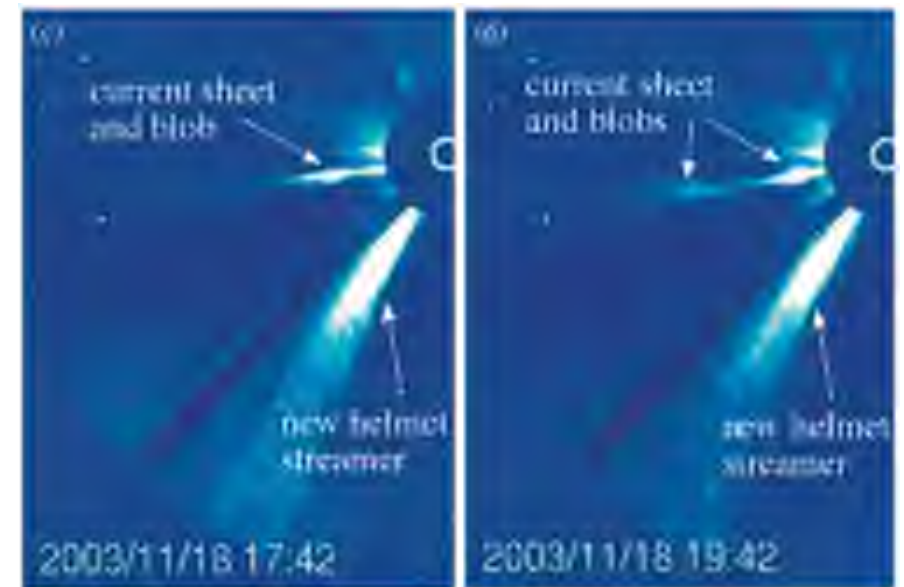


Fig 4



Different from Plasmoid Observations

Fig 1

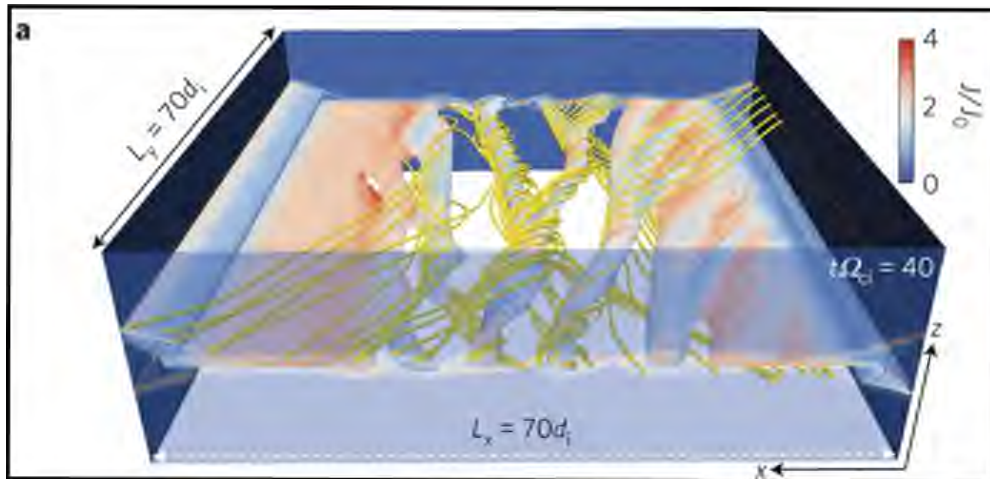
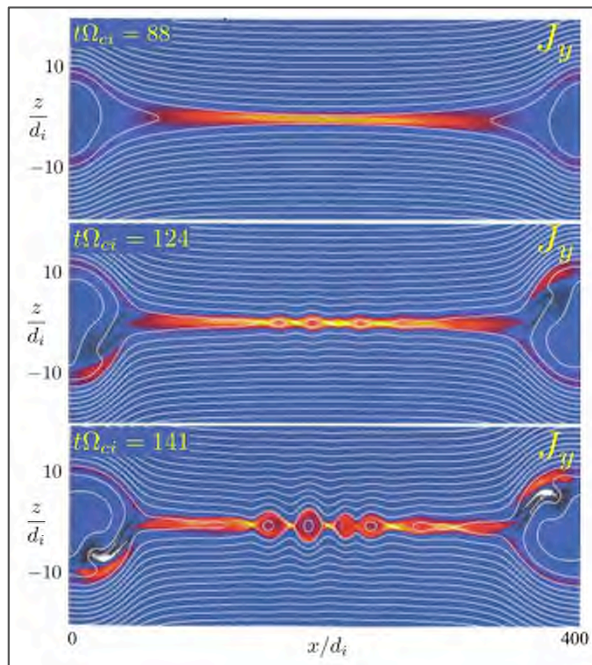
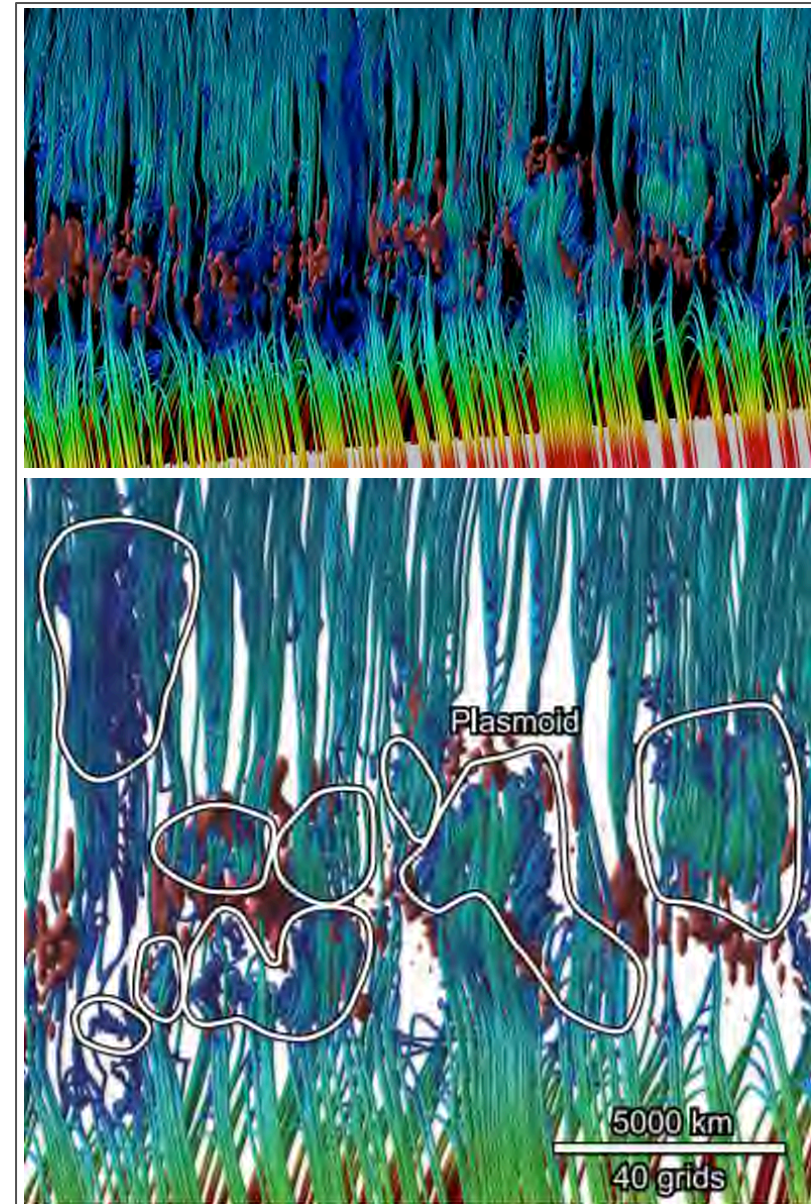


Fig 2

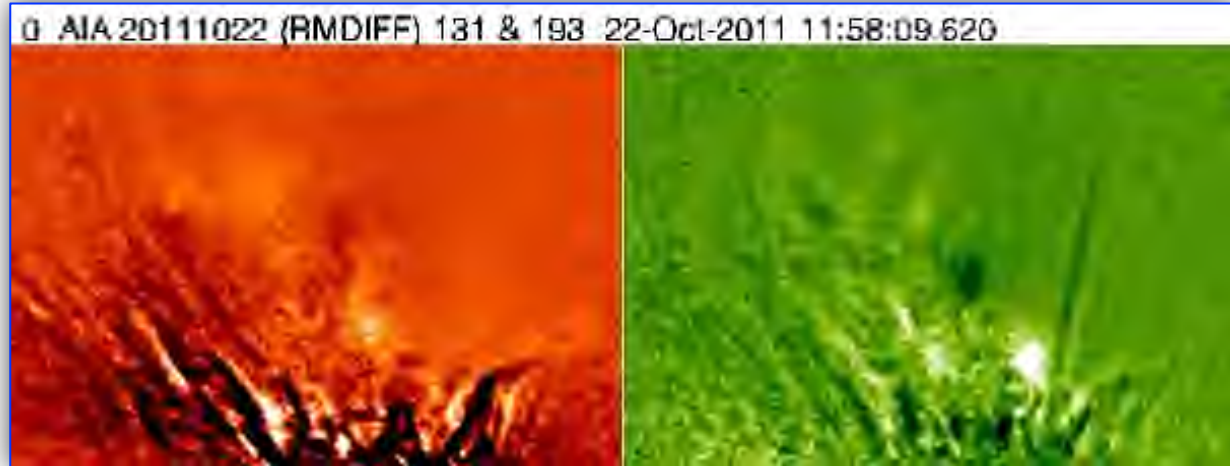
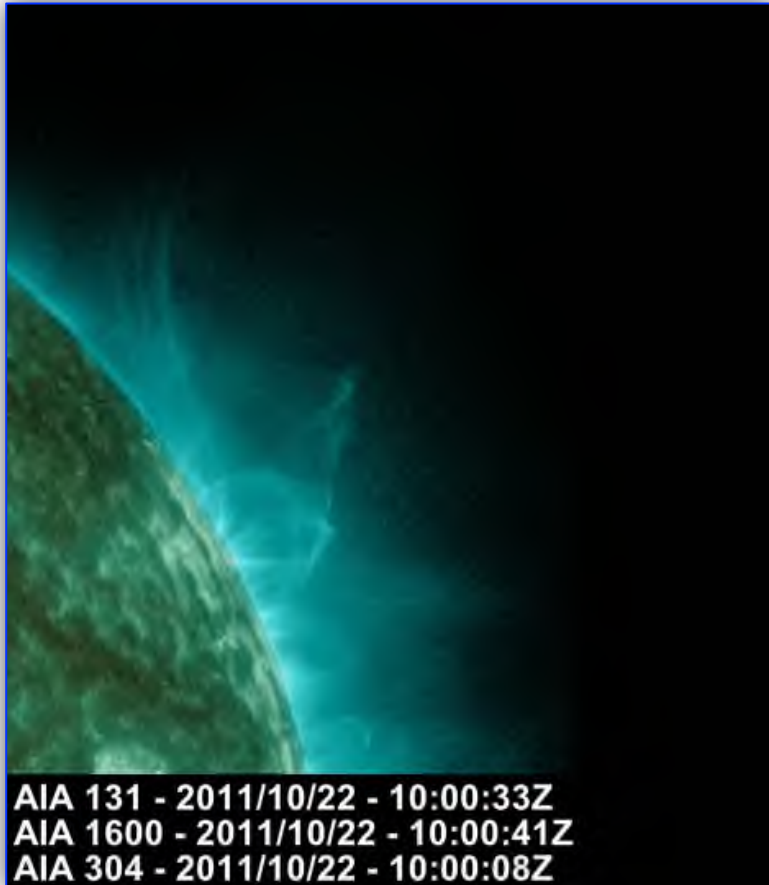


- Thin flux tubes created during the reconnection process across the current sheet.
- Plasmoids a 3-D product of reconnection concurrent to single loop creation.

Fig 3



SADs + SADLs

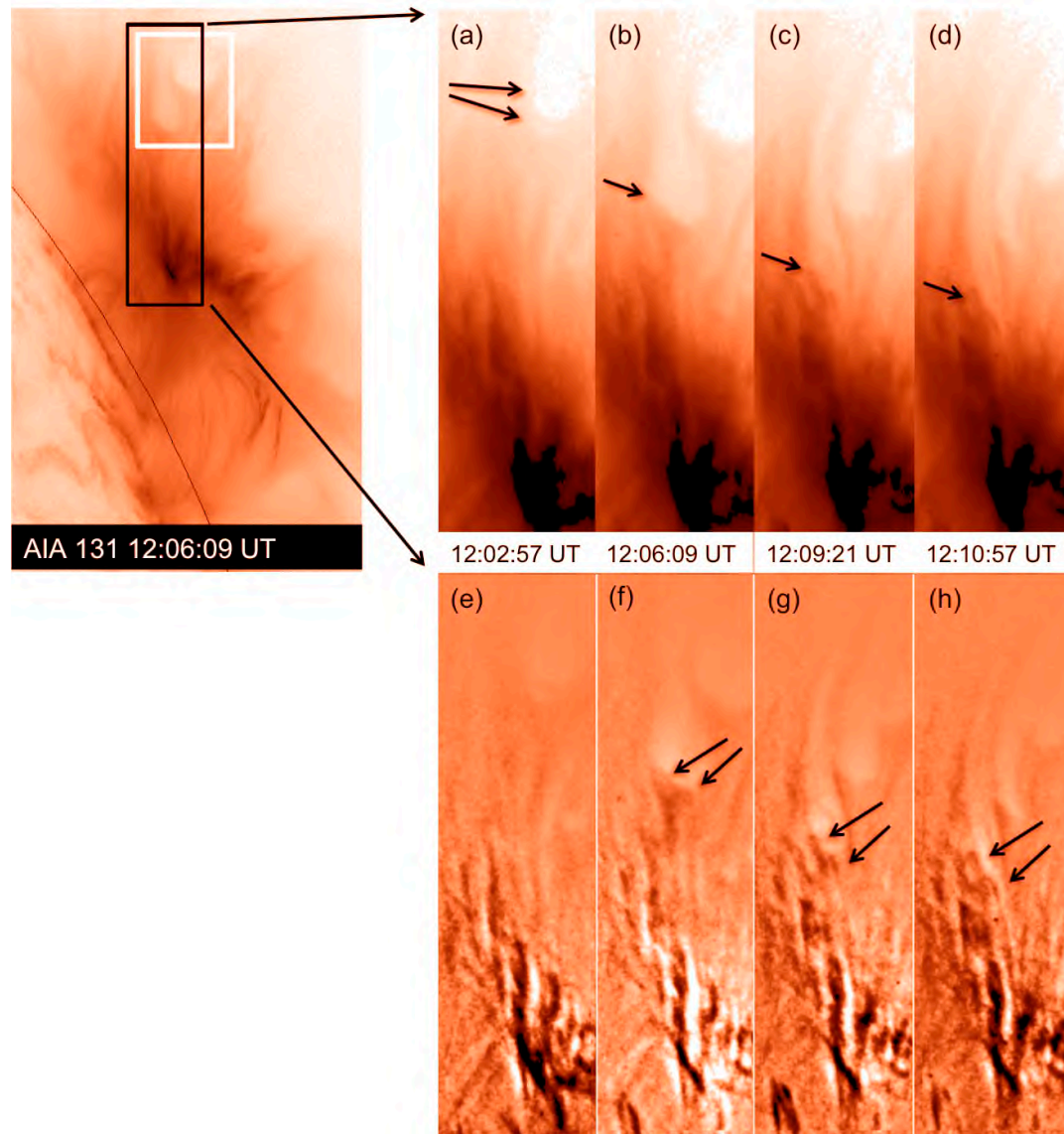


- Hot AIA channels. (2-10 MK)
- Differenced
- Reverse-scaled



SADs + SADLs

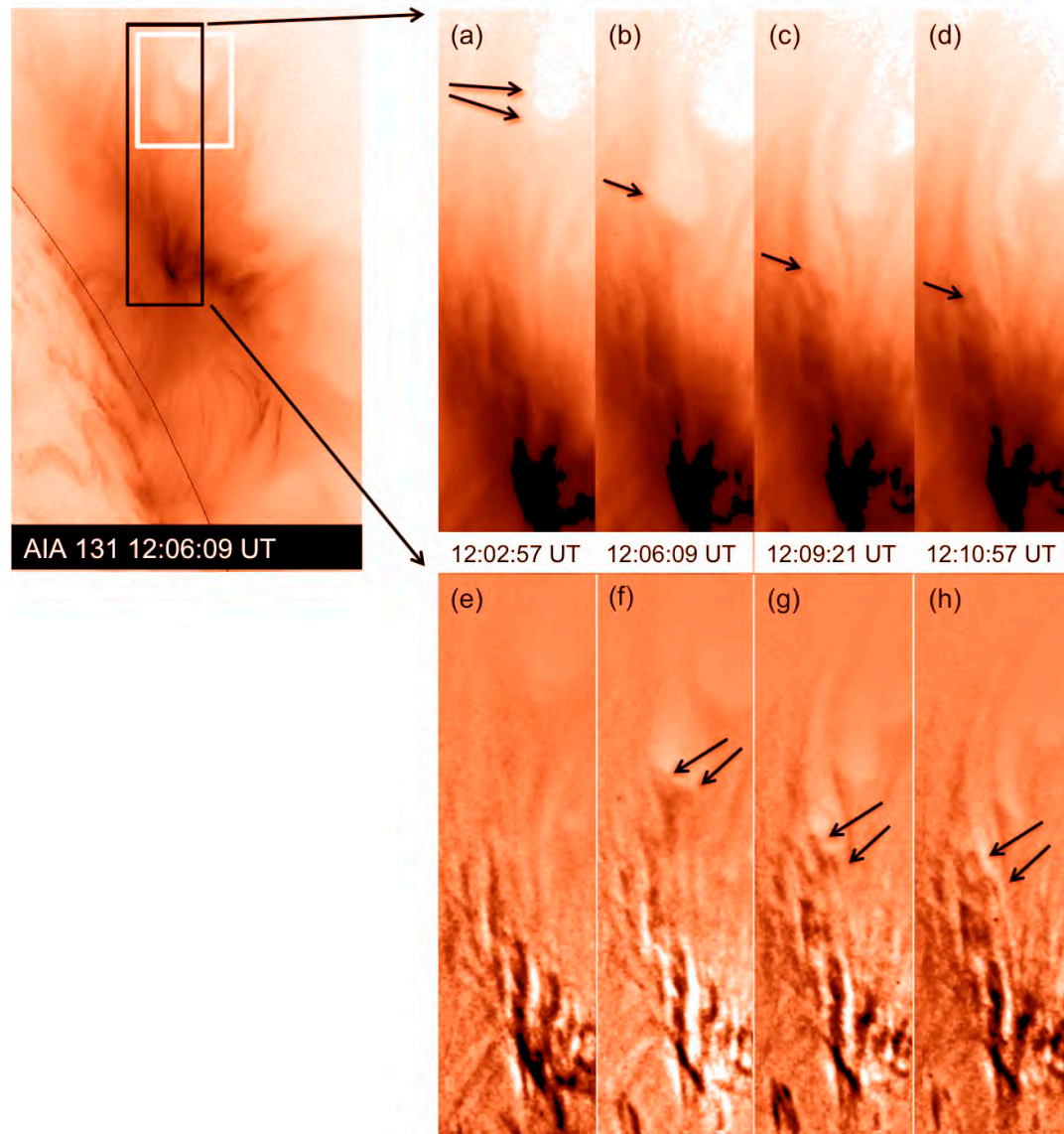
Fig 1



- SADs appear to be voids created by loops (SADLs) shrinking through the fan plasma.

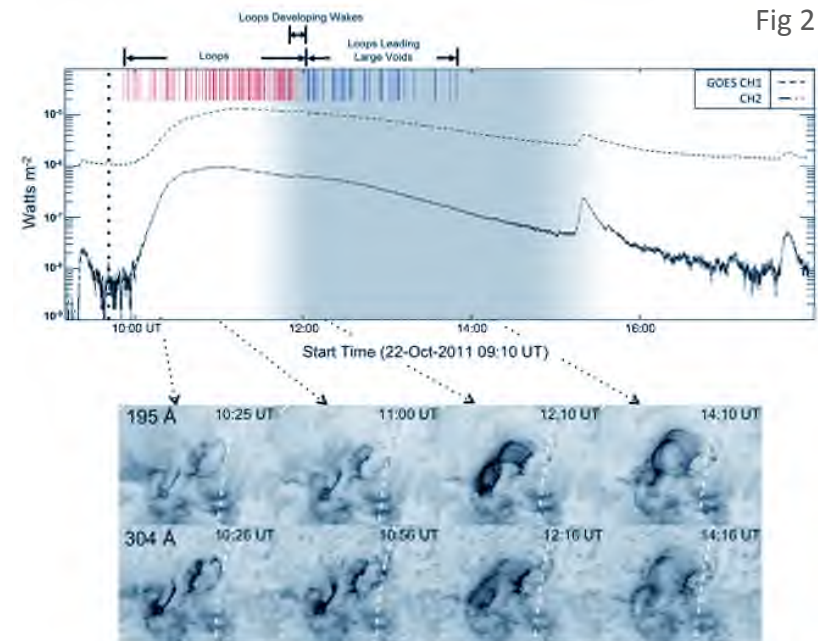
SADs + SADLs

Fig 1

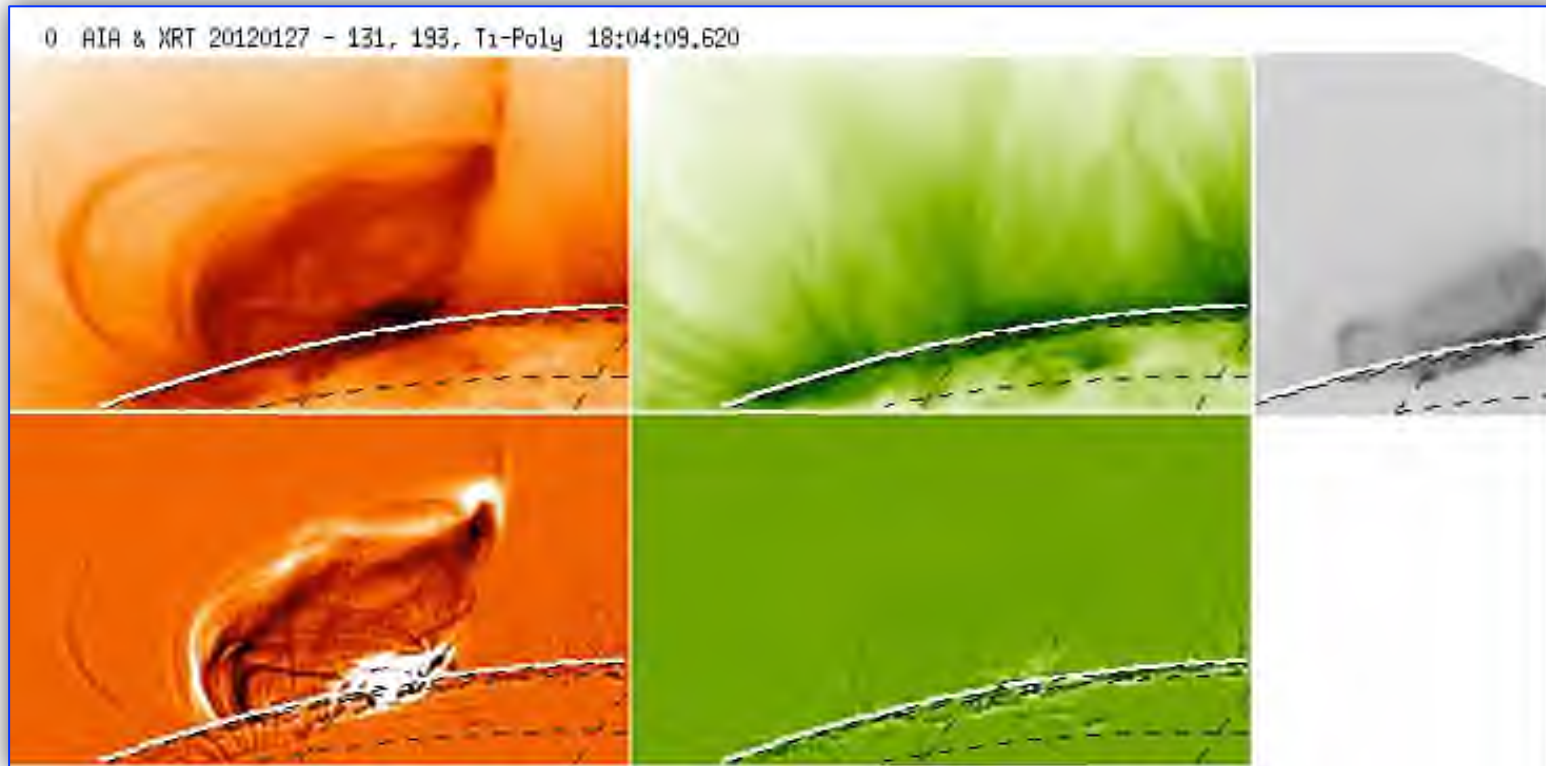


- SADs appear to be voids created by loops (SADLs) shrinking through the fan plasma.

Fig 2



Supra-Arcade Downflowing Loops (SADLs) Observations



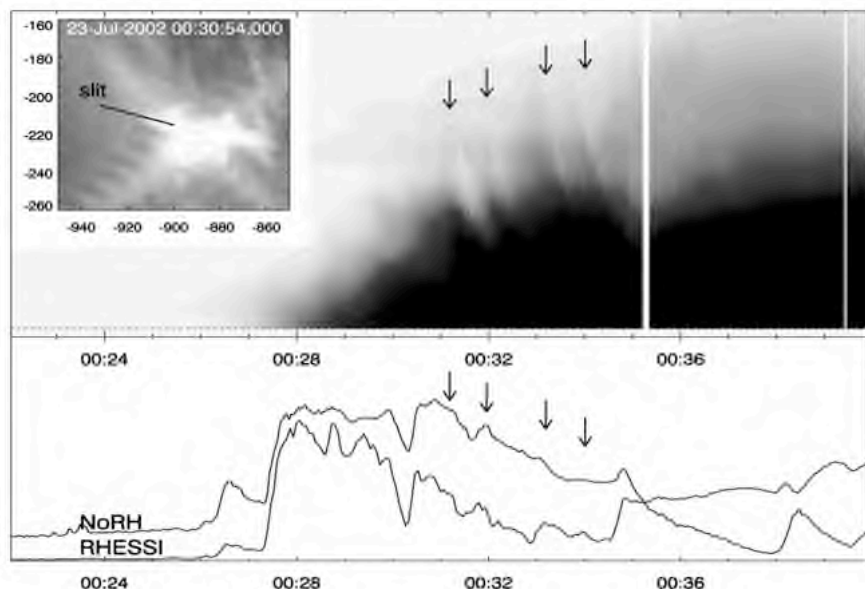
2012 Jan 27, SDO/AIA



Particle Acceleration & Heating

RHESSI + TRACE

Fig 1



VLA + AIA + RHESSI

Fig 3

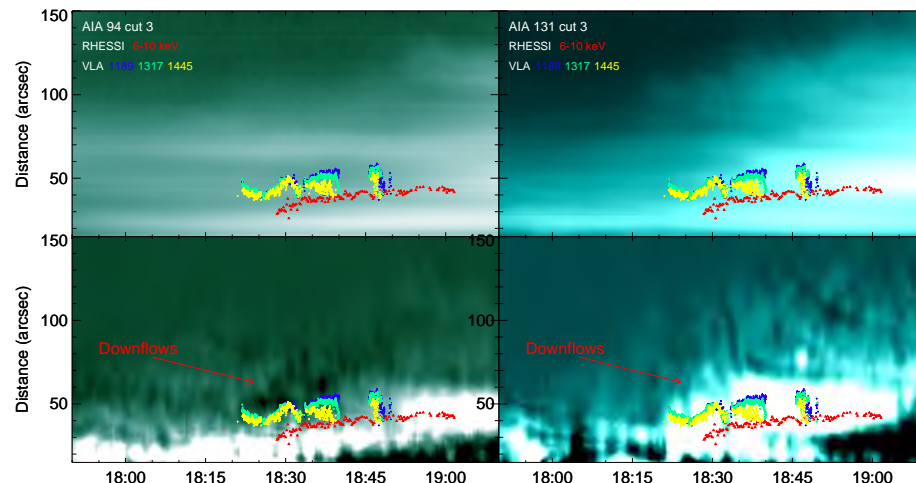
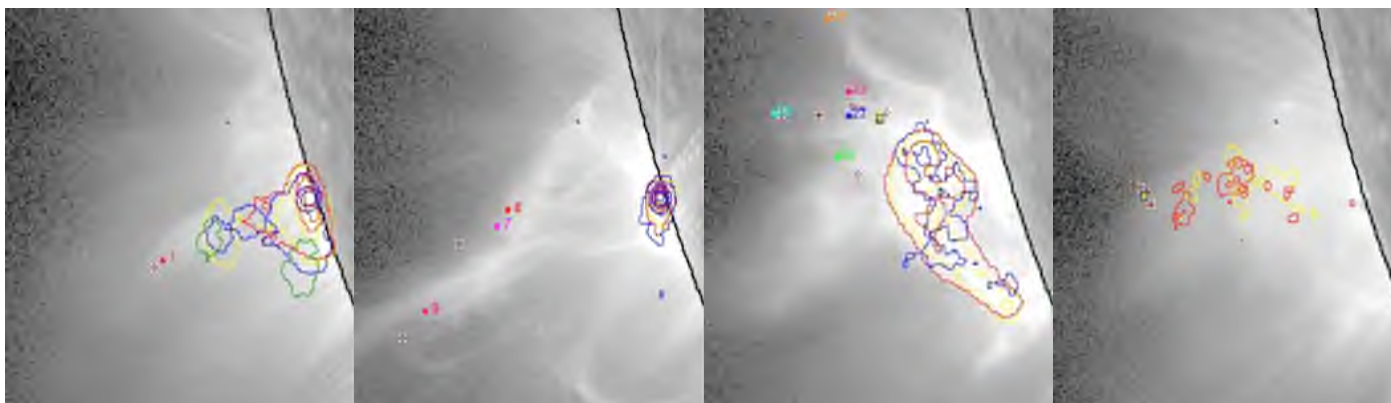


Fig 2



RHESSI + AIA

Savage – 2010 Nov 3 flare

Diagram Models

Fig 1

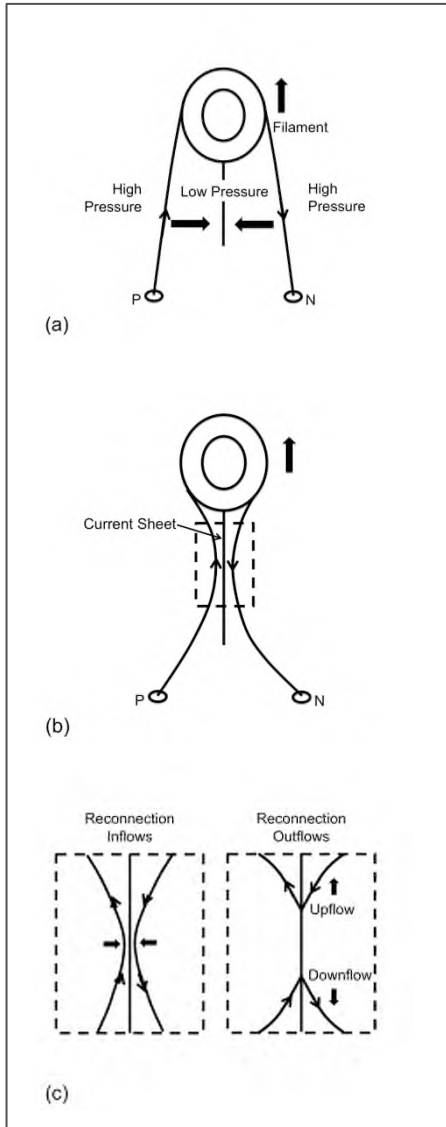


Fig 2

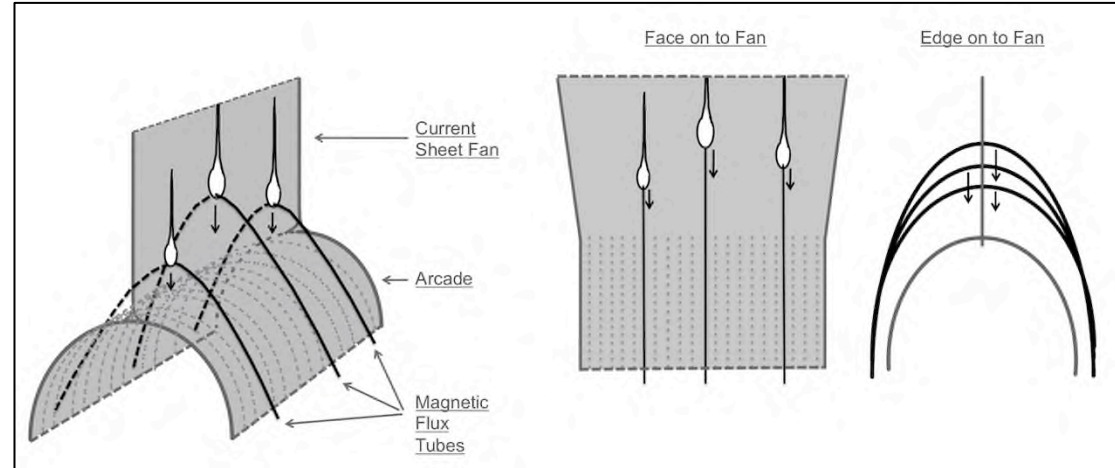
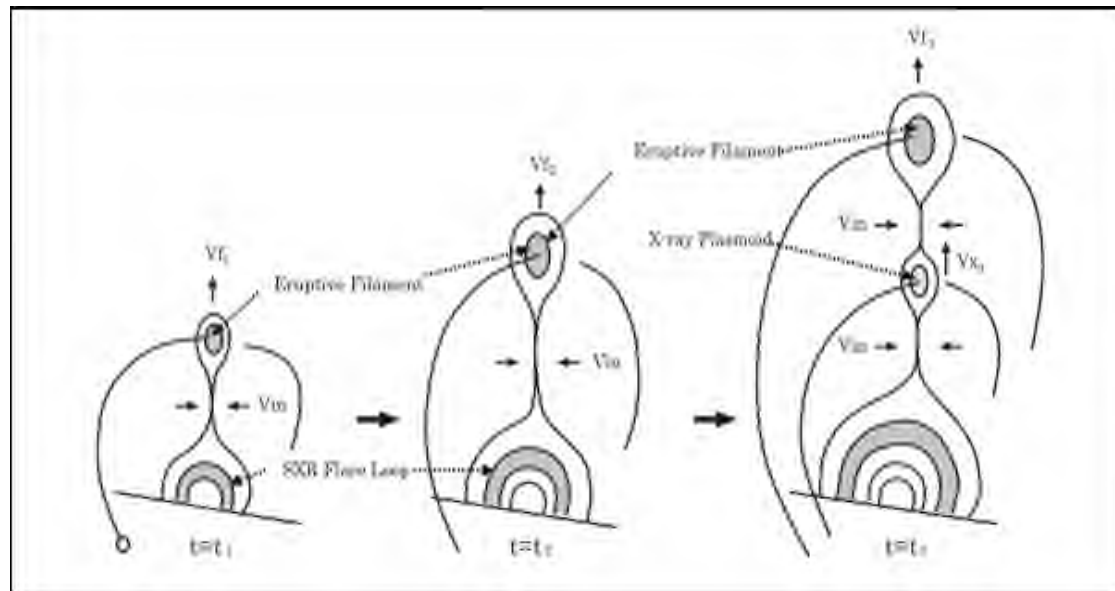


Fig 3



3D is Pivotal

Fig 1

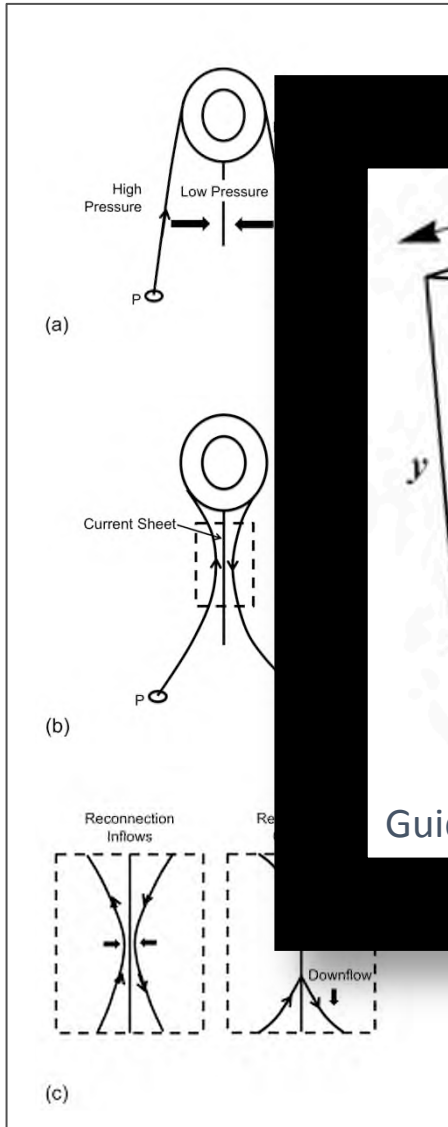
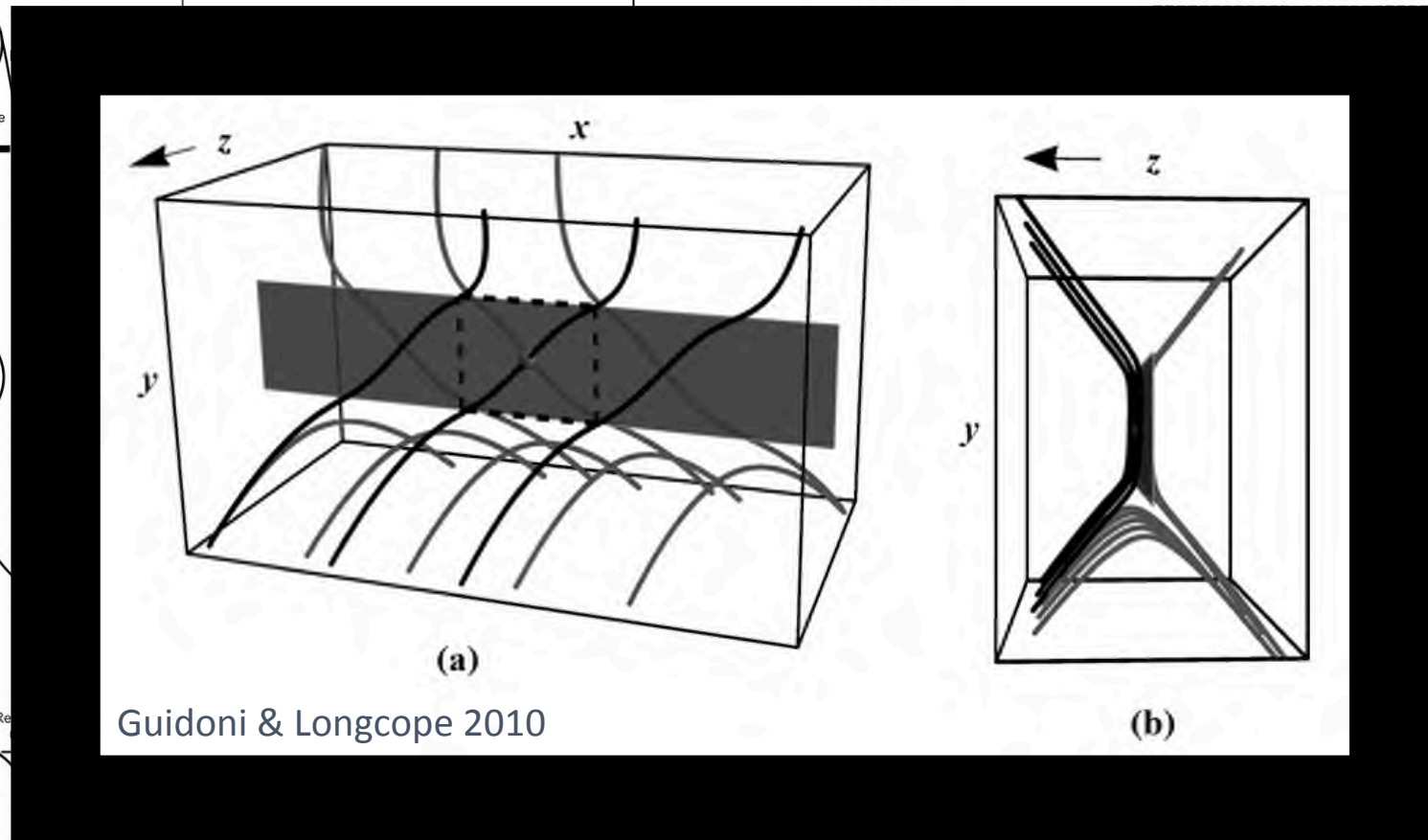


Fig 2



Guidoni & Longcope 2010

Face on to Fan

Edge on to Fan

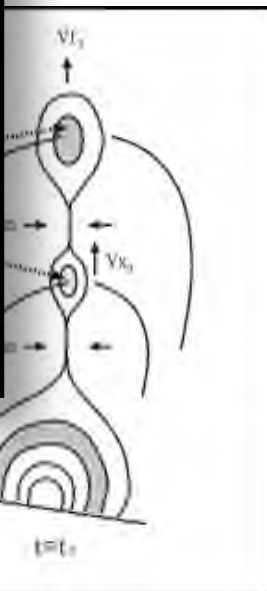
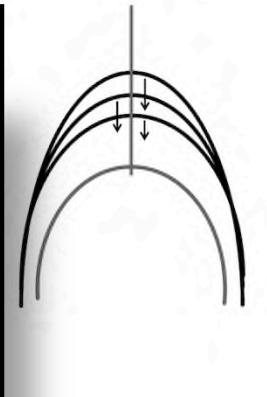


Fig 3

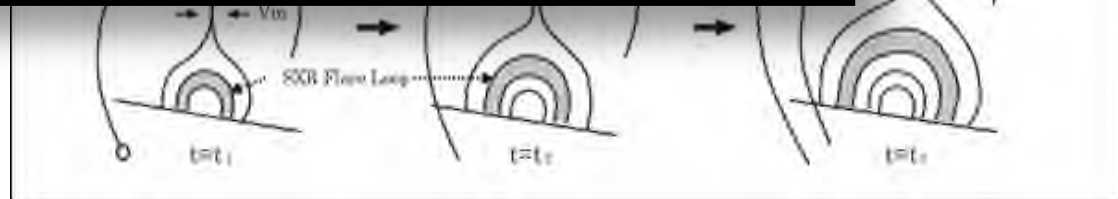
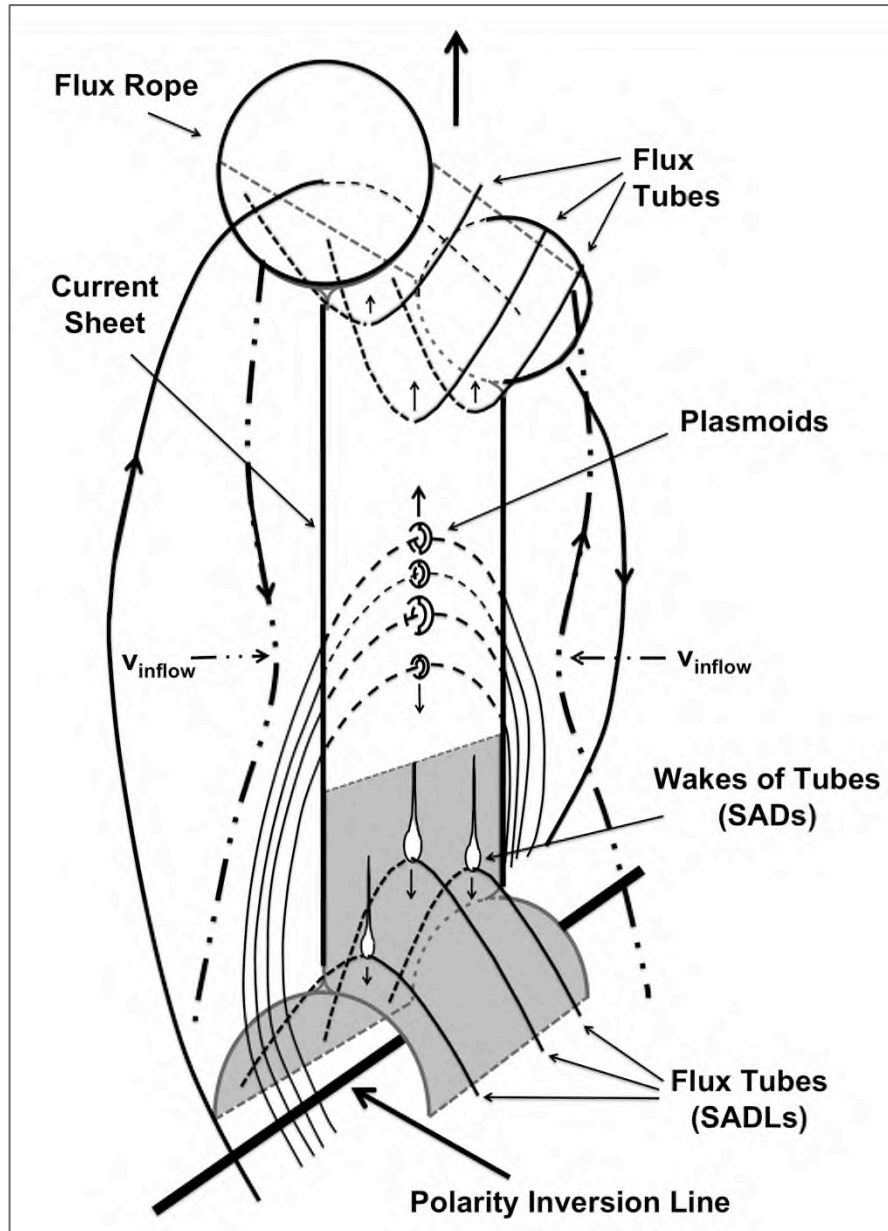




Fig 1



- Basic reconnection scenario, post initial flux rope formation and release.
- General organization of the magnetic field of the various components (SADs, SADLs, plasmoids).
- Field lines reconnect across the current sheet to form outflowing flux tubes while plasmoids form along the current sheet.
- SADs are formed as the flux tubes (SADLs) retract through hot plasma in the fan (*otherwise, only SADLs are observed*).

Strong potential analogy with magnetotail substorms

Fig 1

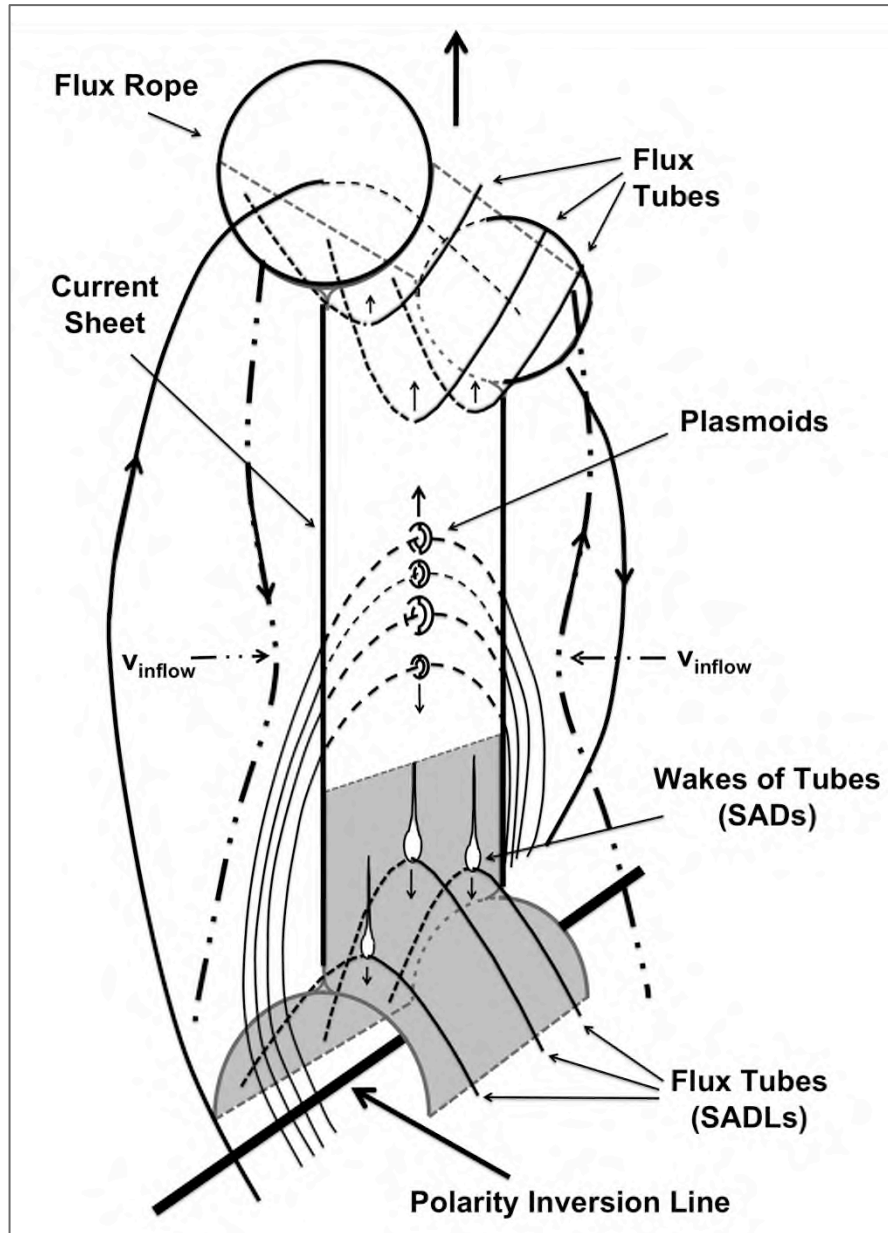
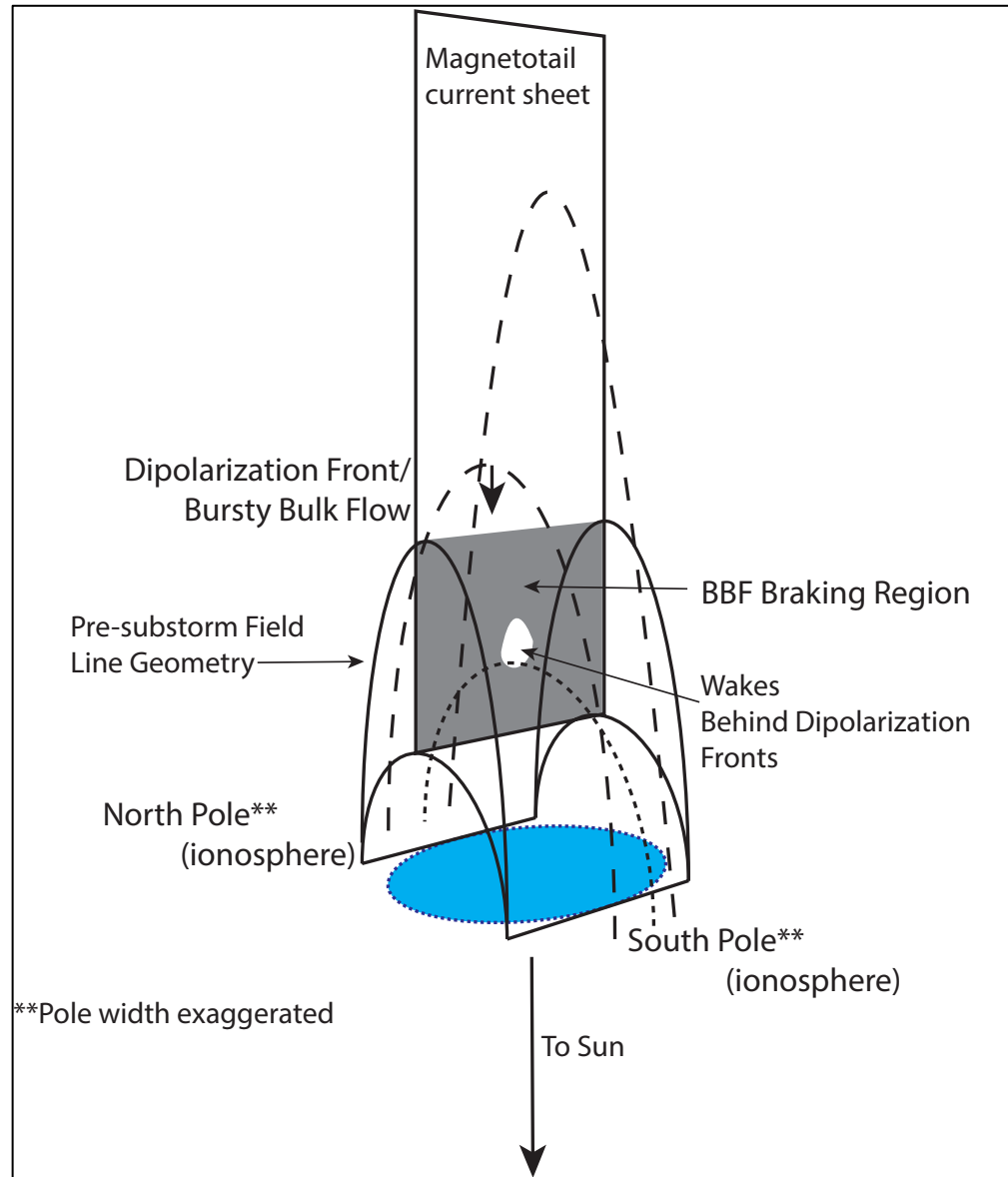
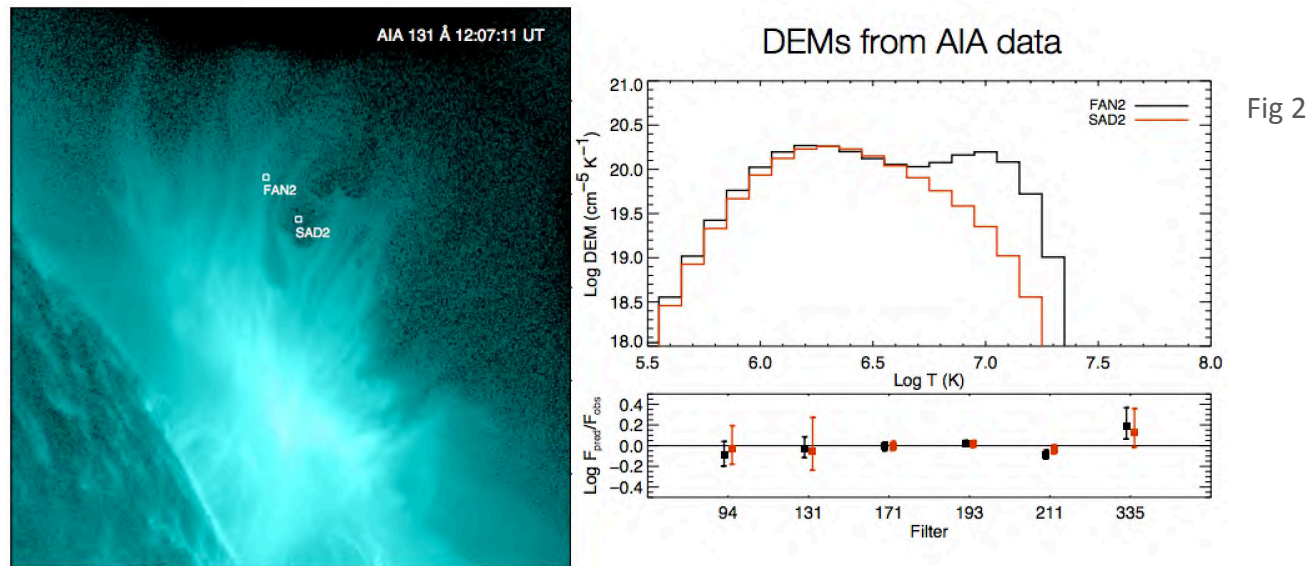
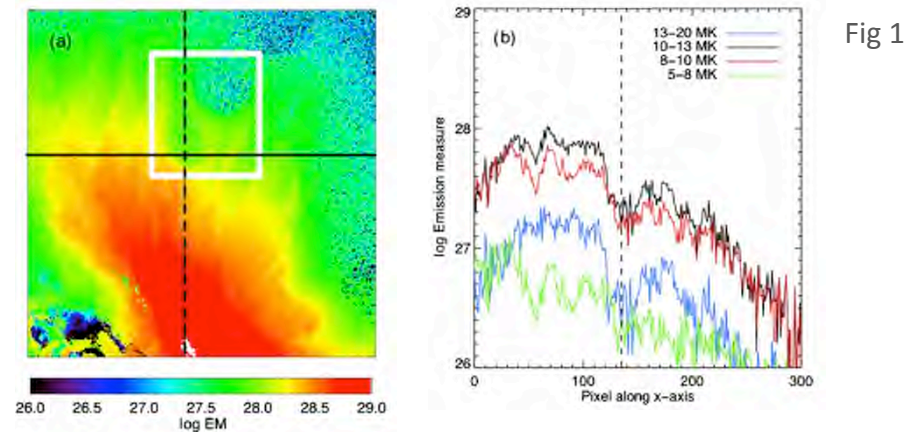


Fig 2

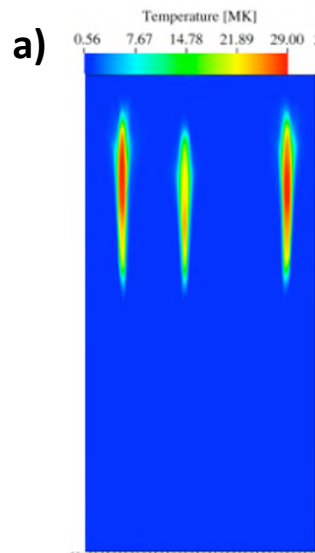


Model Constraints

OBSERVED TEMPERATURE AND DENSITY ALWAYS LOWER THAN FAN



Model Simulations

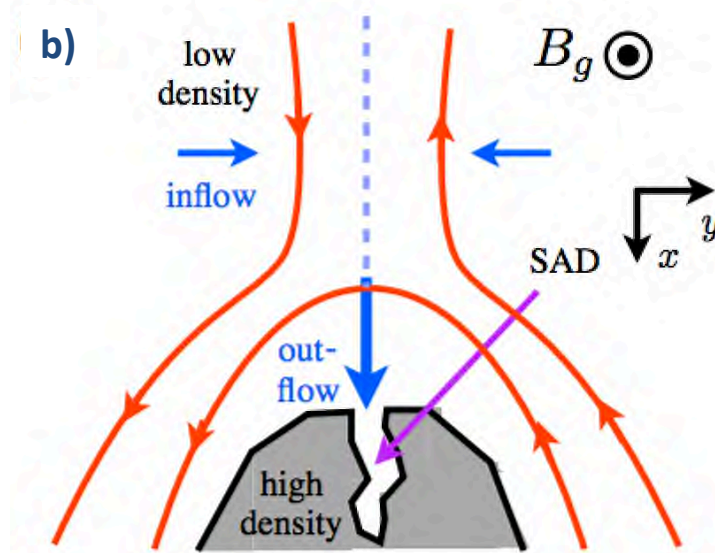


Pressure pulse + MHD wave

($T \gg \text{fan}$)



Too hot with respect to the surroundings

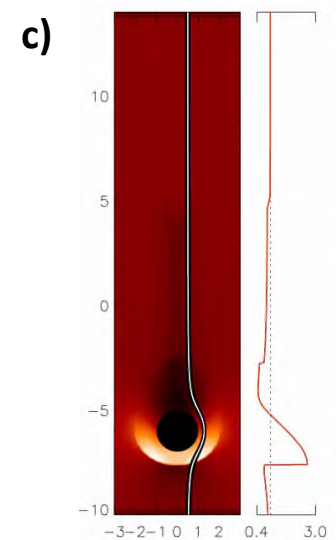


Reconnection outflows

($T \sim < \text{fan}$)



Incorrect geometry with respect to observations



Peristaltic pumping

($T \sim < \text{fan}$)

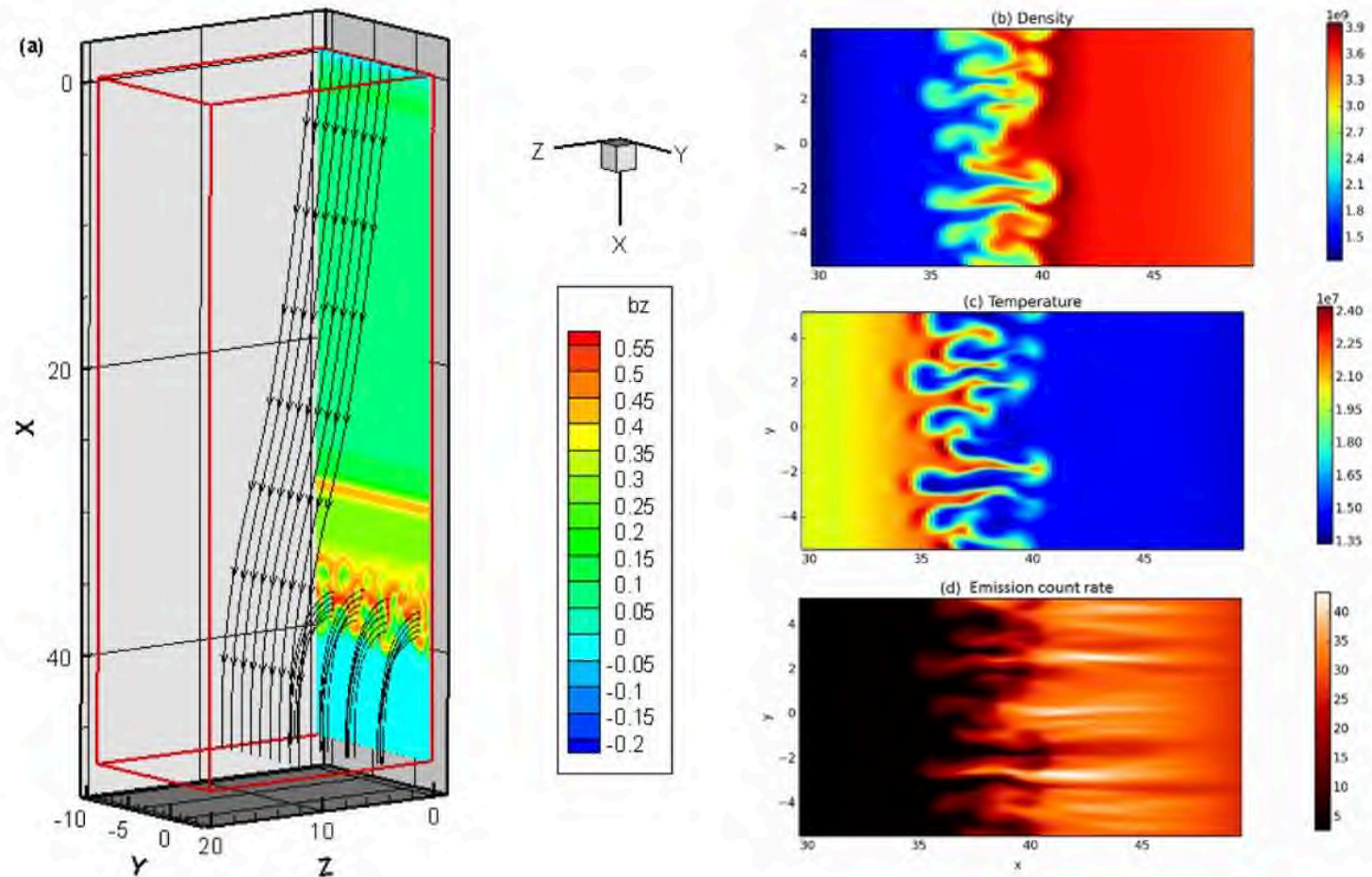
Incomplete, feasible;
Difficult to match to
observations

Fig 1: Cecere et al 2012

Fig 2: Cassak et al 2013

Fig 3: Scott et al 2013

Model Simulations



Rayleigh-Taylor Instabilities behind retracting flux tubes ($T > \text{fan}$)

Too hot with respect to the surroundings

BUT

Best match to observations to date (3D!!!)
although early in development

SADs in the Extended Corona

Fig 1

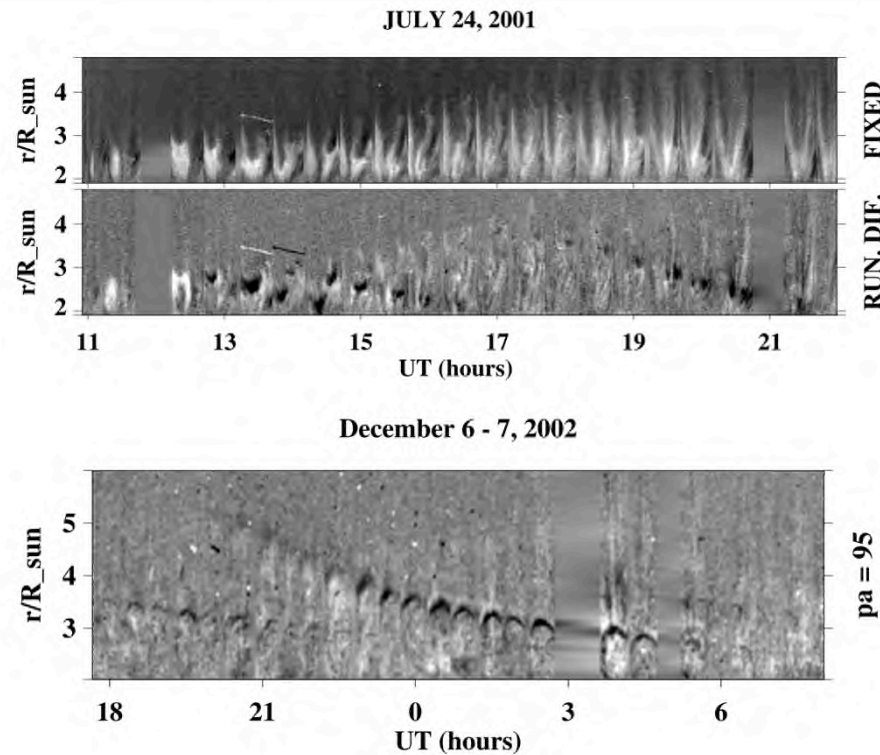
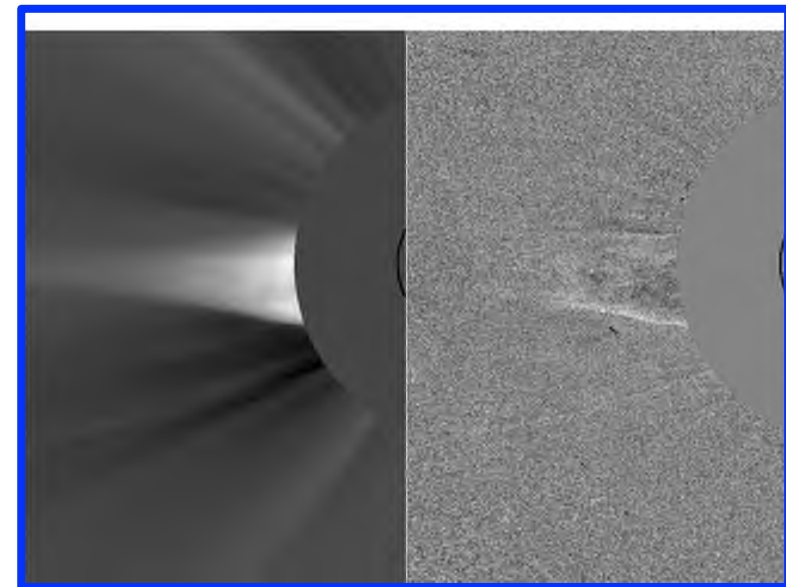
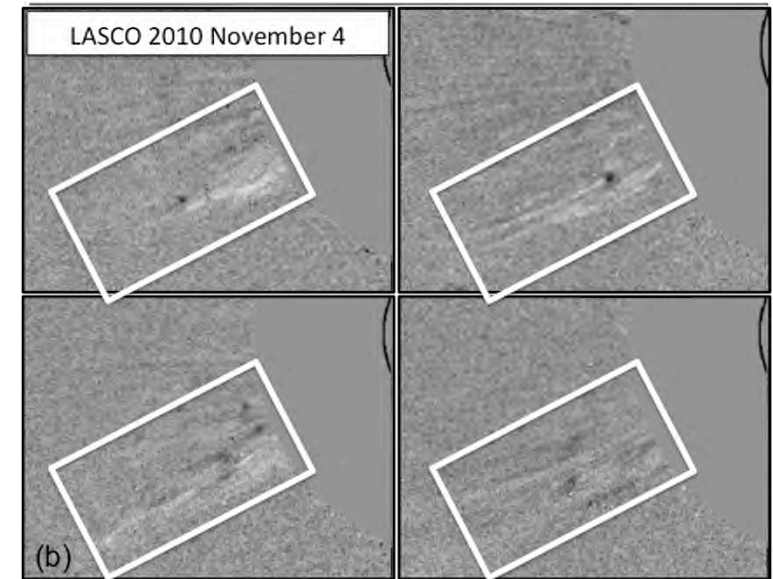
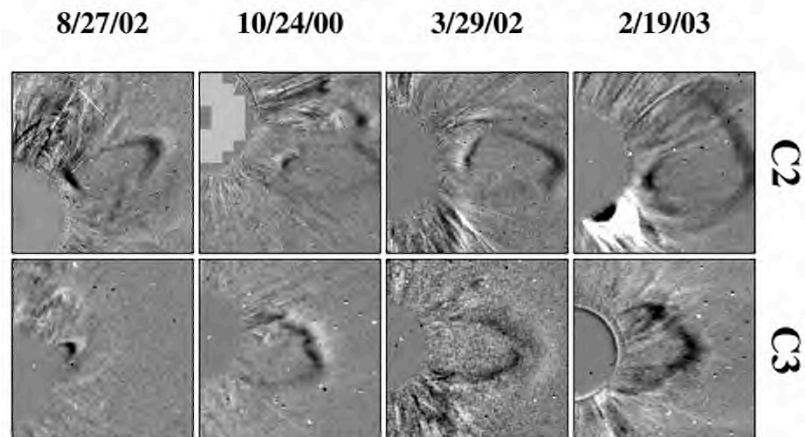


Fig 2

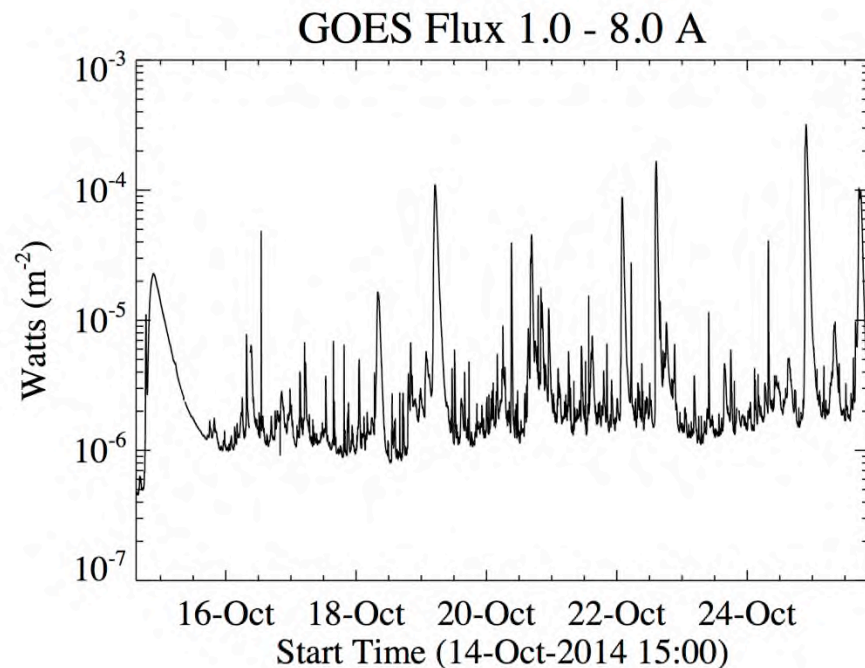


SADs in the Extended Corona...

SADs in the lower corona are typically observed well after reconnection has occurred.

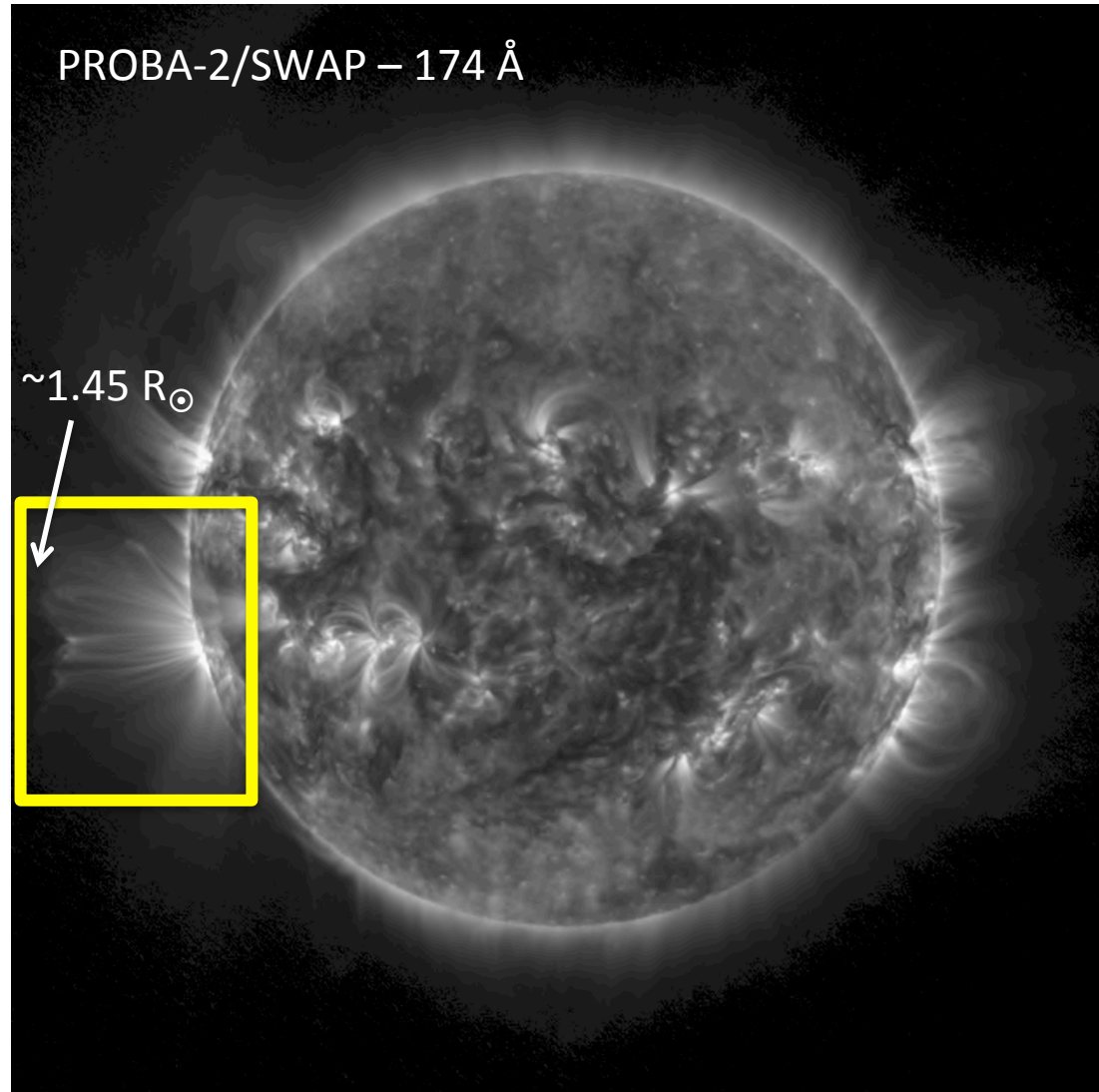
In the extended corona, we are better able to observe the migrating reconnection sites.

Coronagraphs allow us to see reconnection develop behind the CME while looking directly at the density.



“Giant Arches” Flare – 2014 Oct 14

Fig 1



SADs in the Extended Corona...

LASCO C2

PROBA-2/SWAP

AIA 131 Å

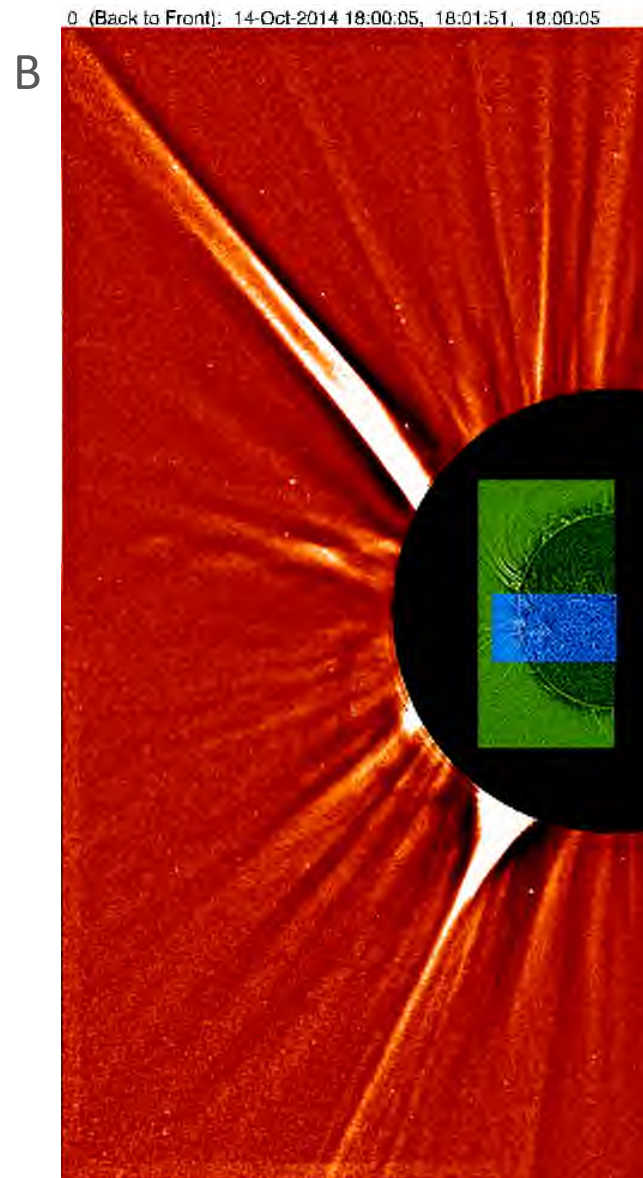
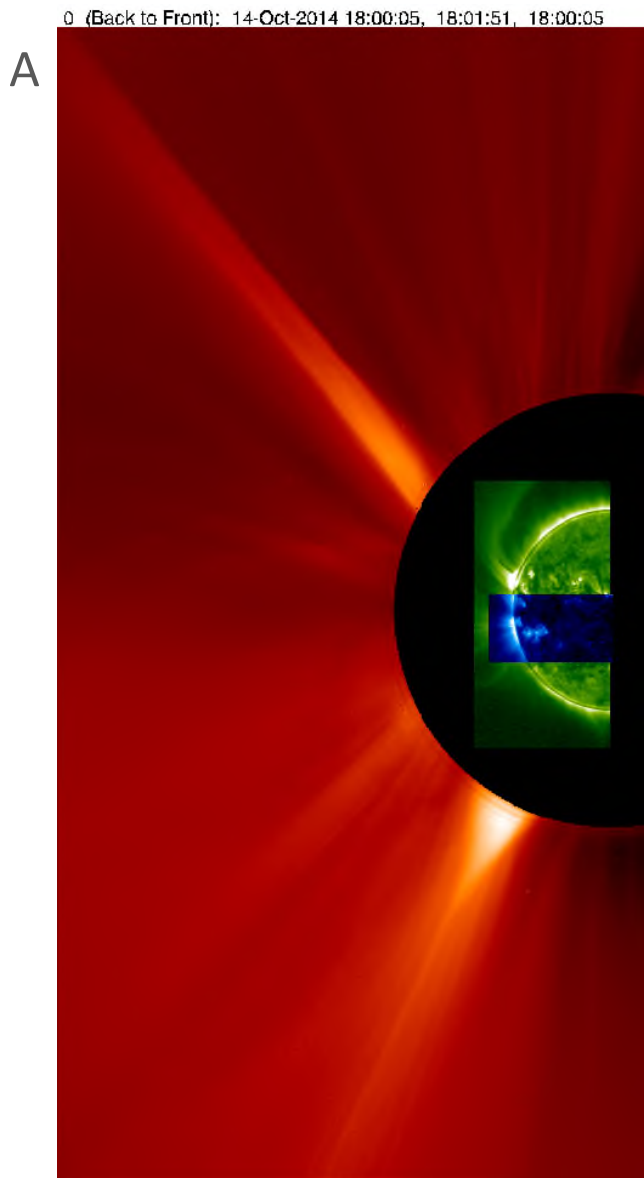
A: Flattened from a year's
worth of data

Cleaned (cosmic
rays, background
stars, planets)

Attenuated disk

B: Smooth-Differenced

- Scaled



SADs in the Extended Corona...

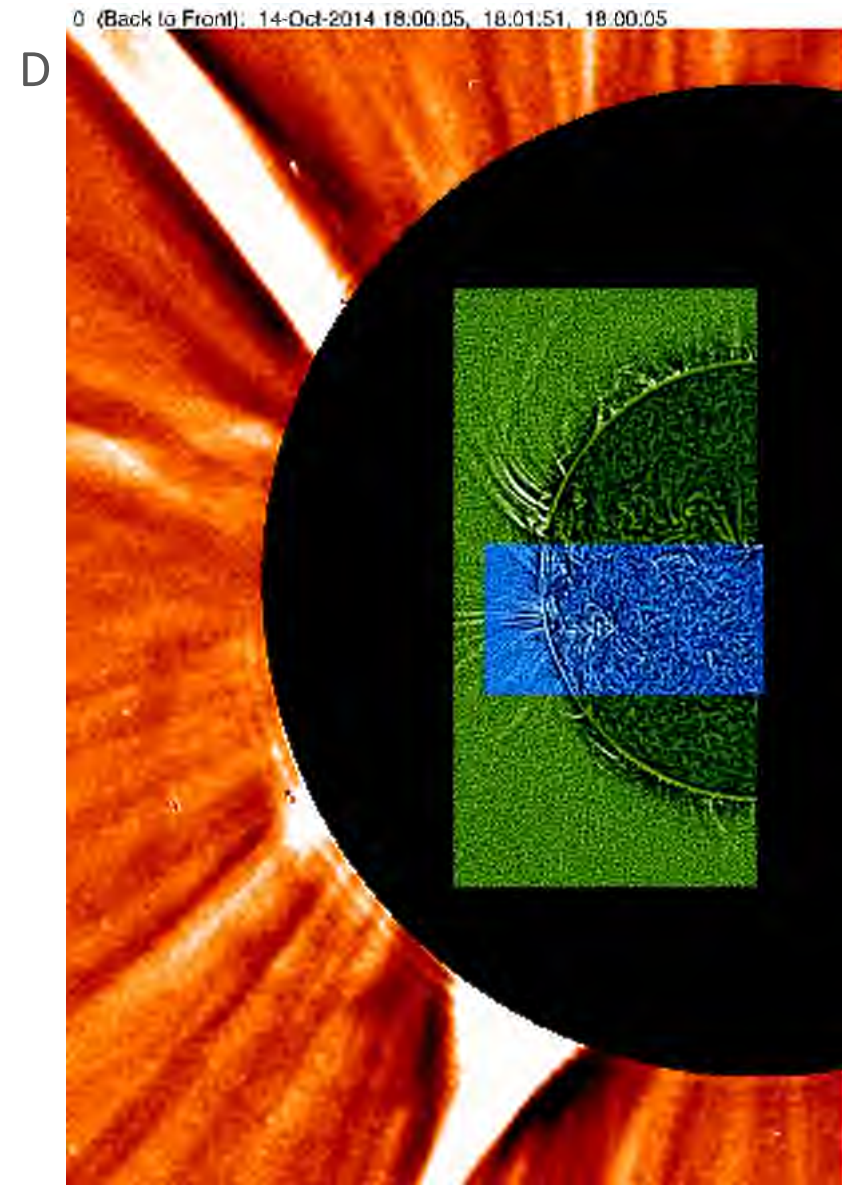
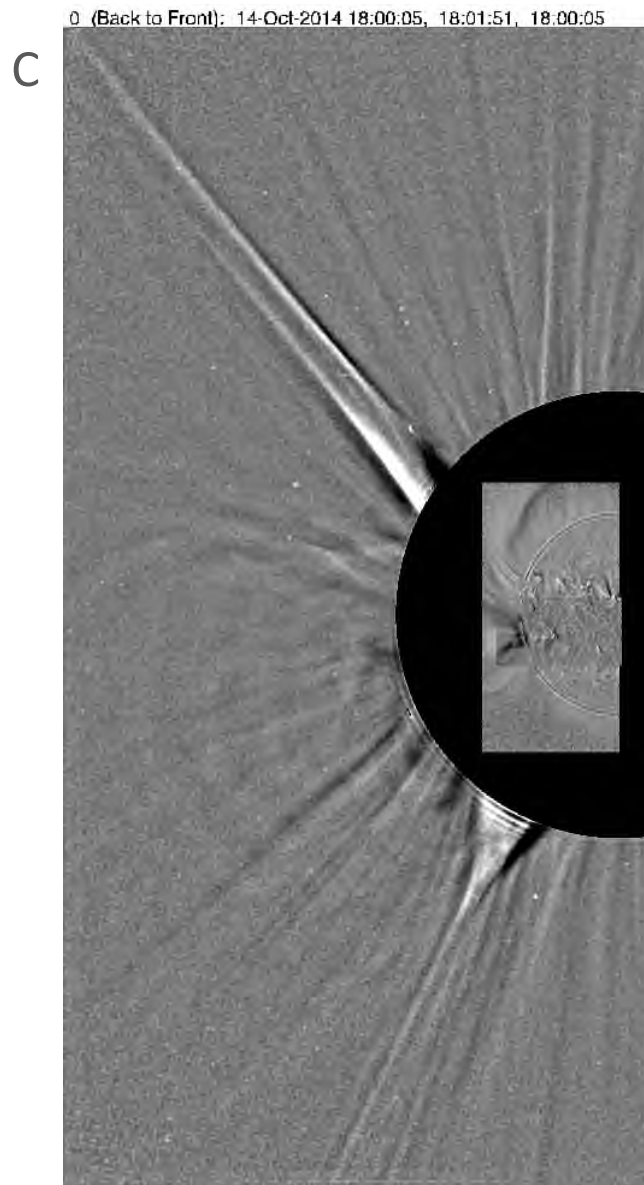
LASCO C2
PROBA-2/SWAP
AIA 131 Å

C: Run-Mean-Differenced

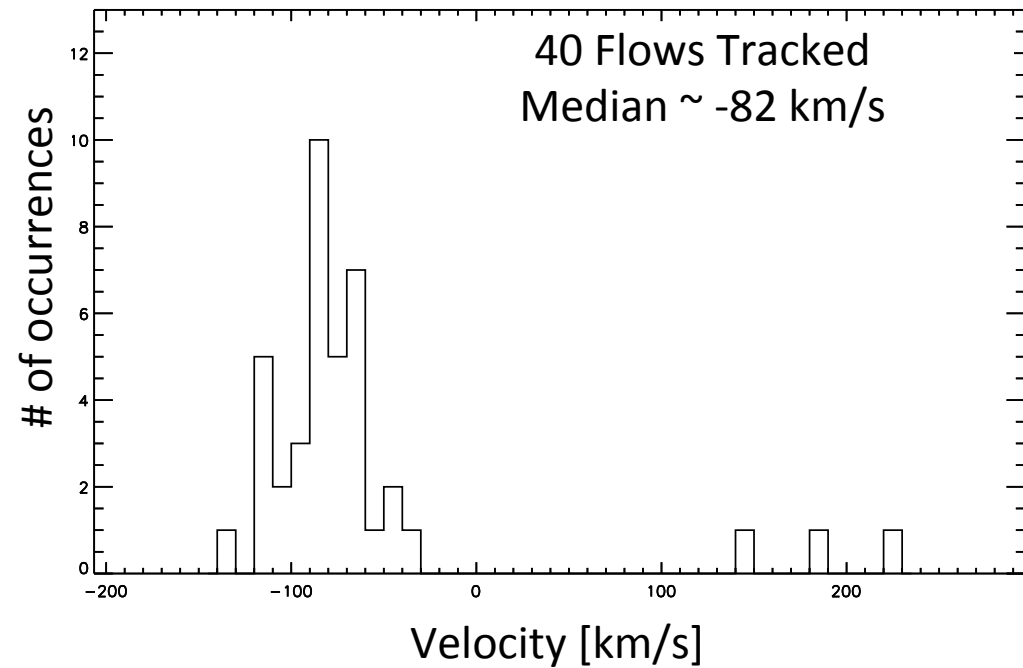
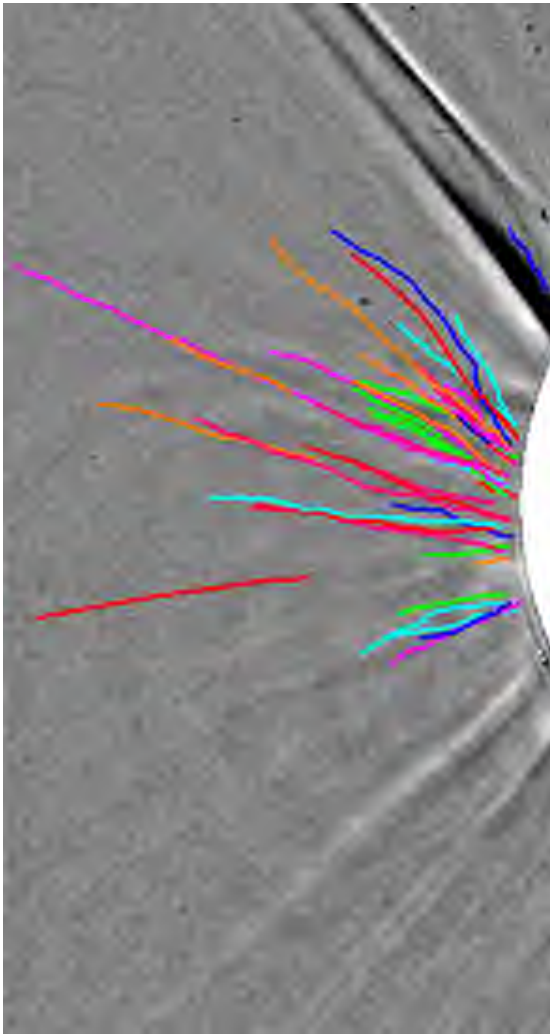
D: Smooth-Differenced

Extracted

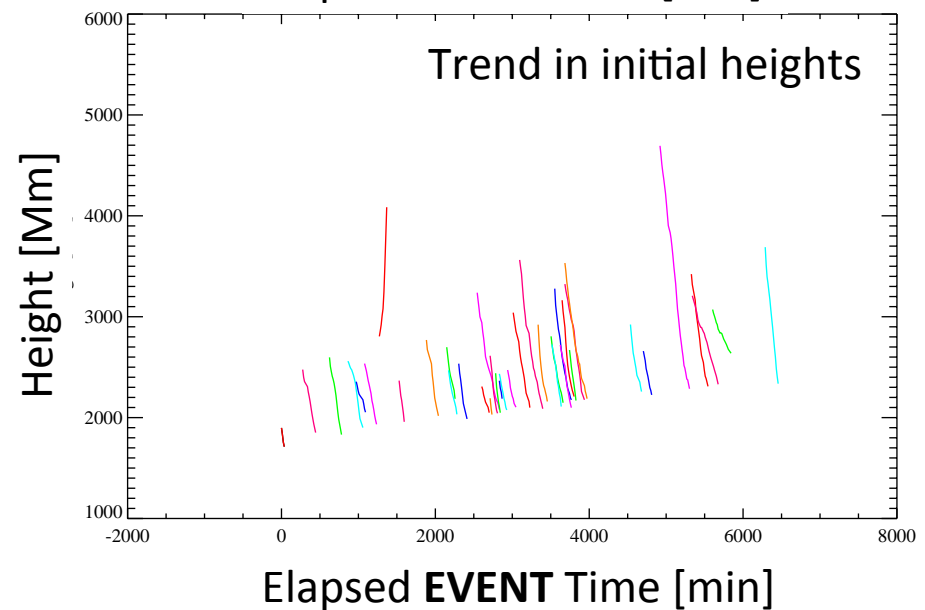
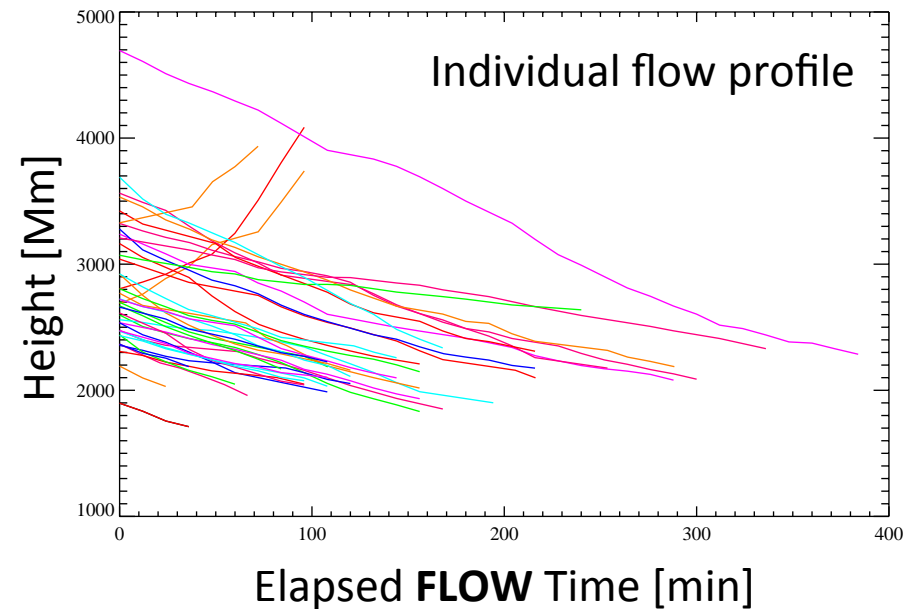
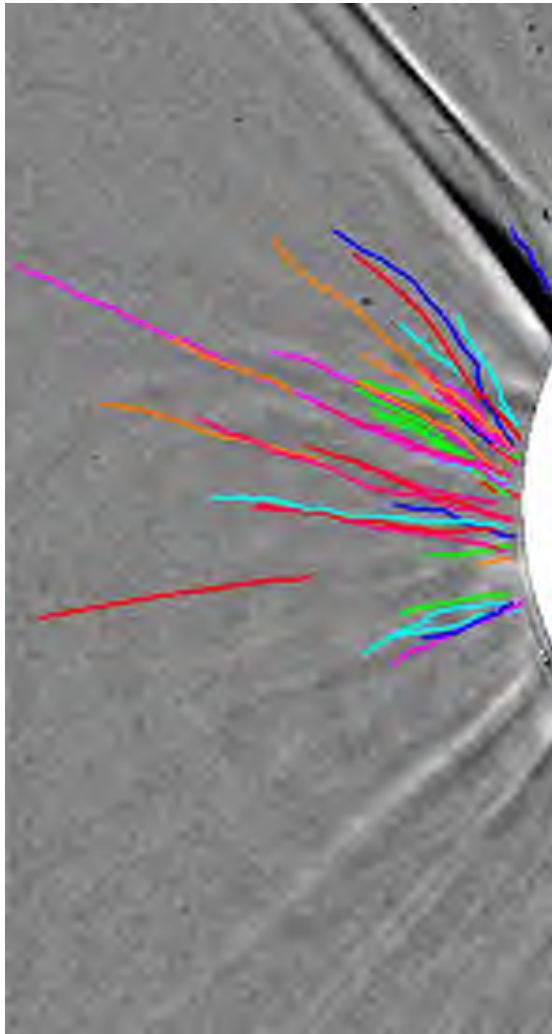
- Scaled



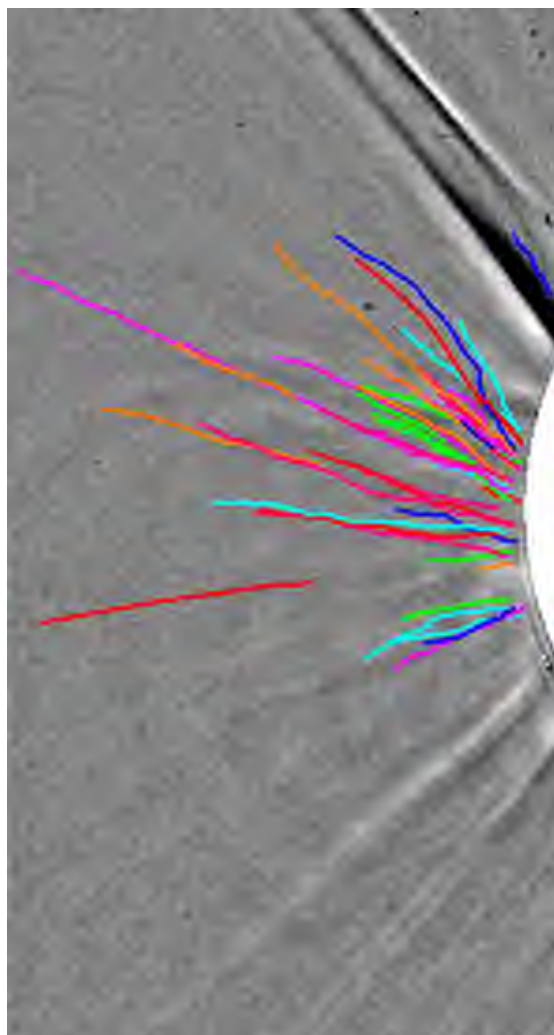
SADs in the Extended Corona...



SADs in the Extended Corona...

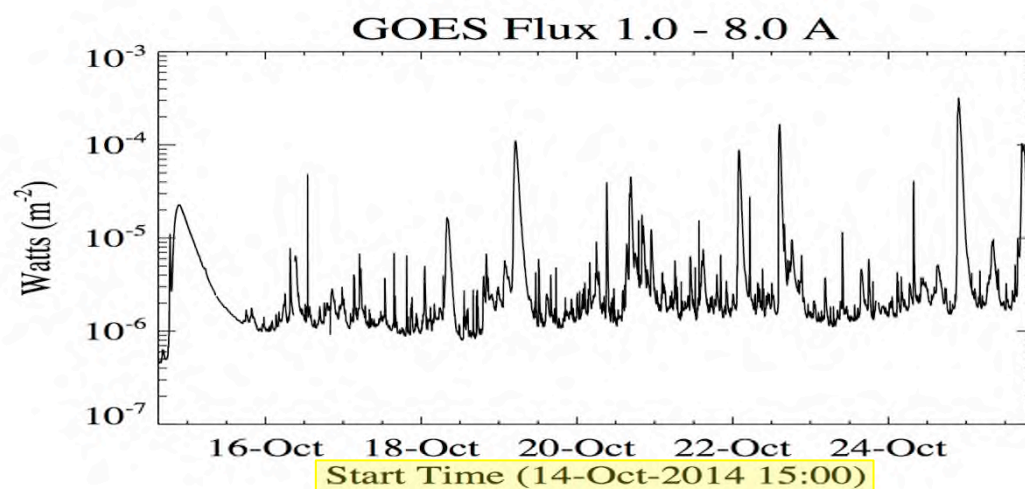
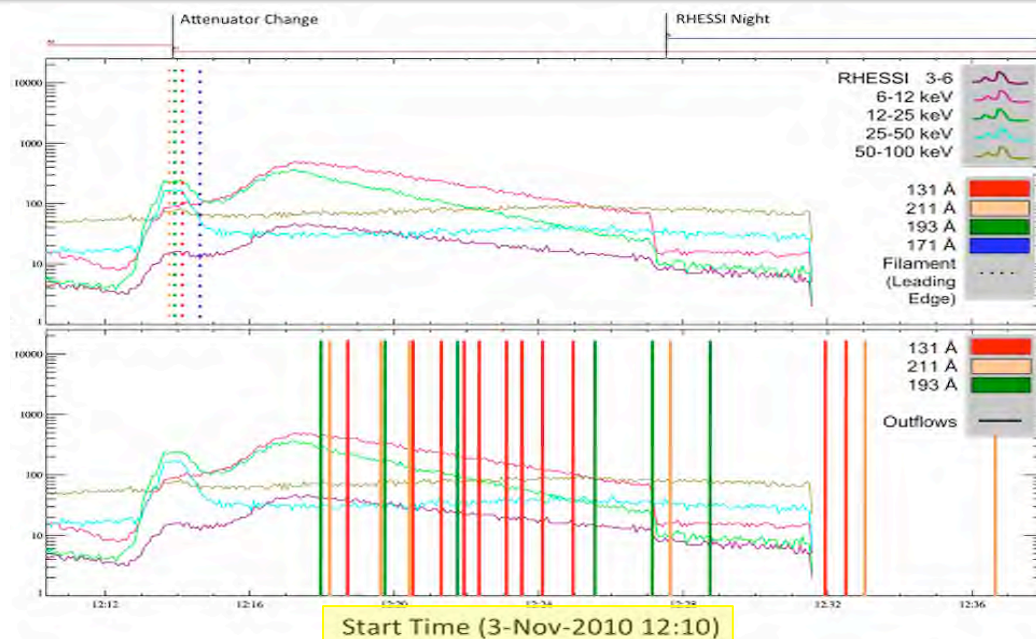


SADs in the Extended Corona...



TBD

1. Correlate flows directly to lightcurve as done for 2010 Nov 3rd event
2. Spatially and temporally correlate RHESSI and Hinode/XRT X-ray contours with outflows.





Summary & Forward Work

- Continuation of shrinking loops imparts energy into the current sheet long after the flare. Clearly.
 - But for an entire week??
 - Does this happen all of the time?
 - How did this one grow so large?
 - Density stratification? Active region interactions?
- Reconnection is fast and patchy.
- Add Hinode/XRT and RHESSI data (started).
- Do features track between fields of view both ways?
 - Initial work begun. (Some even in LASCO C3.)
- Need for instrumentation to fill the gap in observing the transition corona
 - Important to be in single wavelength
 - Possibly coming to an International Space Station near you....

